Cloud Altitude Change Causes Global Temperature Change

by

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The temperature range of the 20th century spans about 0.74 C. Of this, about 40% or 0.3 C has excellent correlation with the sunspot time-integral. An equation has been derived that calculates average global temperature based on the physical phenomena involved. With inputs of accepted measurements (source web links are given) from government agencies, it calculates the average global temperatures (agt) since 1895 with 88.4% accuracy (87.9% if CO2 is assumed to have no influence). This research is presented at Reference 1 and links given there.

Clouds radiate energy from the planet. Cloud elevation determines cloud temperature and thus the energy rate. The analysis presented here determines that an increase in average cloud altitude of only about 72 meters results in an increase of steady-state average global temperature of 0.3 Celsius degrees. Svensmark2 has shown that more sunspots correlate with fewer low-level (below 3 km) clouds. If there are fewer low-level clouds then average cloud altitude must be higher, average cloud temperature lower, less energy radiated from the planet and thus the planet warms.

Steady-State Energy Balance
The overall approach is to determine base values that balance energy flows and then to determine how each of these values must change in response to a change in average cloud temperature.

As a starting point in the analysis, the flow of energy is determined partly using estimates from other sources, some rational refinements, and conservation of energy considerations. A graphic that was copied from a NASA site3 is useful as a qualitative description of the various energy flows. It is shown below with some revisions. Some energy flows are more explicitly defined than at the NASA site and the values presented there are replaced by symbols (alpha characters) with values determined herein.
Svensmark determined that more sunspots resulted in fewer low level (<3 km) clouds. If there are fewer low-level clouds then the average cloud altitude would be higher. This gives rise to the question that is addressed in this paper of how the steady-state surface temperature would be influenced by change to average cloud altitude.

The general approach used here to determine this is to establish a baseline of values that balance energy flows on the above graphic and then to determine how the surface temperature changes as the cloud temperature changes.

The following demonstrates that higher average cloud altitude would result in increasing average global temperature as occurred during the solar grand maximum of the last half of the 20th century. All energy rates are in watts per square meter.

**Calculation of the Magnitudes of Energy Flow**

Measured values of energy from the sun vary only slightly depending on the solar cycle and slight other long-term variations in the ‘solar constant’. The value used here is 1365 W/m². The energy from the sun is intercepted by the planet according to the cross section area but is distributed according to the surface area so this is divided by 4 to account for the ratio of surface area to cross-section area of a sphere.

\[ Q = \frac{1365}{4} = 341.25 \text{ W/m}^2 \]

Part of this incident energy is reflected. The fraction of the incident energy that is reflected is often assumed to be determined by the earth’s albedo which, from what appears to be a credible source, is about 0.297. However, albedo is primarily diffuse reflection and does not include Fresnel-type low-incidence-angle specular reflection from the 71% of the planet that is covered by water. The fraction of the total energy reflected from the planet is slightly higher than that determined by albedo alone and is about 0.308 (my calculation).

\[ R = Q \times 0.308 = 105.105 \text{ W/m}^2 \]
The amount of energy reflected from the clouds and atmosphere was determined as required to maintain the same ratio of cloud+atmosphere reflection to surface reflection as is reported by Kiehl and Trenberth\textsuperscript{5}.

\[ A = \frac{R}{1+23/79} = 81.4 \text{ W/m}^2 \]

Part of the remaining energy is absorbed by clouds and atmosphere. I selected a value of 48% for this to be consistent with the absorbed energy rate assessment by Kiel & Trenberth\textsuperscript{5}. A comparison of the 1997 and 2008 K & T values along with corrections are shown on page 3 of Ref 6. An additional factor of 0.6 accounts for the observation that clouds cover about 60% of the planet.

\[ B = (Q-A) \times 0.48 \times 0.6 = 74.84 \text{ W/m}^2 \]

The energy that gets through the atmosphere is simply that which is not reflected or absorbed by the clouds and atmosphere.

\[ C = Q - A - B = 185.01 \text{ W/m}^2. \]

The part of this that is reflected by the surface is simply that part of the total reflection that was not reflected by the clouds and atmosphere.

\[ D = R - A = 23.71 \text{ W/m}^2. \]

The energy that is absorbed by the surface is the part of C (the entering energy that got through the atmosphere) that is not reflected.

\[ E = C - D = 161.31 \text{ W/m}^2. \]

The energy leaving the surface as convection (thermal), evaporation (latent) and radiation from the surface that directly leaves the planet are all as presented on the K & T chart.

\[ F = 17 \text{ W/m}^2 \]
\[ G = 80 \text{ W/m}^2 \]
\[ J = 40 \text{ W/m}^2 \]

The radiation from the surface is gray-body radiation as calculated by the Stephan-Boltzman equation. Most (71%) of the surface of the planet is covered by sea water with an emissivity of about 0.995 at water temperature. Part is from snow with emissivity of about 0.99 and the rest is from land that is mostly about 0.99 but with a few small local areas that are substantially lower. The over-all average emissivity from the surface is taken to be 0.99. The average global temperature is taken to be 288 K as typically reported. The S-B constant, \( \sigma \), is 5.6697E-08 W/m\(^2\)/T\(^4\). (Temperature in degrees Kelvin)

\[ U = 0.99 \times 5.6697 \times 288^4 = 386.16 \text{ W/m}^2 \]

Clouds are fine particles of liquid water or ice and thus also radiate according to the S-B equation. Clouds cover about 60% of the planet and have an average emissivity\textsuperscript{7} of about 0.5. Their average temperature was determined to be 258 K in an entirely different analysis that produced an average global temperature of 288K. The thin air and low temperature at high altitude means that there is very little water vapor so radiation up from the clouds nearly all gets directly to space. The small part that doesn’t is ignored resulting in:

\[ P = 0.6 \times 0.5 \times 5.6697 \times 258^4 = 75.36 \text{ W/m}^2. \]

The same energy flux as from the top of the clouds exists also from the bottom of the clouds. The down flux encounters substantial absorption prior to reaching the ground. K
& T report 40 W/m² or 40/396 = 10.1 % of the radiation making it from the surface through the ghg to space. A calculation using data from Barrett⁹ for 60% cloud cover produces 10.8 %. Since about half of the source radiation is stopped by clouds in going from the surface to space and not stopped by clouds when going from clouds to the surface, the fraction getting to the surface is about 21% of that going from the surface directly to space.

\[ K = 0.21 \times P = 15.83 \text{ W/m}^2. \]

The total energy being radiated from the planet must be the amount from the sun minus the amount reflected.

\[ M = Q - R = 236.10 \text{ W/m}^2. \]

The energy radiated from the atmosphere must be the total for the planet minus that just from the clouds to space minus that which goes directly from the surface to space.

\[ N = M - P - J = 120.78 \text{ W/m}^2. \]

The amount of energy that is thermalized can now be calculated from the other values entering and leaving the atmosphere system.

\[ H = M - J + K - F - G - B = 40.13 \text{ W/m}^2. \]

The fraction of radiation from the surface (that does not go directly to space) that is thermalized is

\[ \text{TH} = H/(U-J) = 0.1159 \text{ or } 11.59\%. \]

The energy that is absorbed by ghg and returned to the surface is that leaving the surface minus that going directly to space minus that which is thermalized.

\[ I = U - J - H = 306.02 \text{ W/m}^2. \]

**Effect of cloud altitude change**

Cloud temperature varies with altitude and, on average, varies as presented in the Standard Atmosphere Tables that are widely available. Using the graphic above and the values calculated above as a baseline, required cloud temperature change to produce a given surface temperature change was determined.

The new value for the amount of energy that is thermalized starts with the baseline value. Adjustments are made to it to account for changes to the other values entering and leaving the atmosphere system. Subscript 0 refers to baseline values, s refers to surface and c refers to cloud

\[ H = H_0 + (N - N_0) - (F - F_0) - (G - G_0) + (K - K_0) \]

Thermalization does not change so it is used to determine the new value for the energy radiated from the surface.

\[ U = H/\text{TH}_0 + J \]
Each of the baseline values of energy rate was varied according to a function of a new temperature to the baseline temperature as follows:

\[ B = B_0 \]
\[ J = J_0 \times \left( \frac{T_s}{T_{s0}} \right)^4 \]
\[ F = F_0 \times \frac{T_s}{T_{s0}} \]
\[ P = P_0 \times \left( \frac{T_c}{T_{c0}} \right)^4 \]
\[ G = G_0 \times \frac{T_s}{T_{s0}} \]

This assessment resulted in the following values. Average cloud temperature vs. altitude is from standard atmosphere tables.

<table>
<thead>
<tr>
<th>Avg cloud alt, meters</th>
<th>Steady-state surface temp, K</th>
<th>H</th>
<th>F</th>
<th>P</th>
<th>G</th>
<th>J</th>
<th>I</th>
<th>N</th>
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</table>

The above numerical data for the steady-state average global (surface) temperature that results from change in average cloud altitude is shown in the following graph:

- Surface temperature range attributed to cloud altitude change.
- Change to cloud altitude attributed to sunspot number change.

This graph is actually slightly curved. It appears to be straight because it covers such a small range, although the range is large compared to the magnitude of change in average global temperature that has actually been experienced since accurate temperature measurements have been made.
As previously determined\(^1\) the part of agt change that is not accounted for by effective sea surface temperature change and the tiny bit that might be attributed to the change in the level of atmospheric carbon dioxide is about 40\% of the total or about 0.3°C. A cloud average altitude change of only about 72 meters results in this amount of steady-state average global temperature change.

References: