Modeling of Physical Systems

Radiation balance of the Earth

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1 Aim of laboratory

The aim of the laboratory is to simulate of the global radiation budget of the Earth considering two cases:

- assuming there is no atmosphere
- assuming there is atmosphere

What is more, in this laboratory we were supposed to impement glaciations mechanism (Surface albedo depends on the temperature).

2 Algorithm

Algorithm is basing on set of energy balance equestions. In every scenario we are solving equastion in order to find temperature for specific solar constant.

2.1 No Atmosphere

Equastion to solve for case without atmosphere is following:

$$
\begin{aligned}
P_{S\text{ł}} &= S * \frac{Pow_z}{4} * (1 - A) \\
P_Z &= \sigma * T^4 * Pow_z \\
P_Z &= P_{S\text{ł}}
\end{aligned}
$$

where:

$P_{S\text{ł}}$ – Power of solar radiation arriving to the Earth (short wave radiation)

P_Z – Power of radiation emitted from Earth (long wave radiation)

A – mean albedo of the Earth surface

S – solar constant

Pow_Z – area of the surface of Earth

σ – Stefan-Boltzmann constant

T – wanted value

2.2 With Atmosphere

$$
\boxed{
\begin{aligned}
&(-t_a)(1-a_s)\frac{S}{4} + c(T_s - T_a) + \sigma T_s^4 (1 - a_a') - \sigma T_a^4 = 0 \\
&-(1 - a_a - t_a + a_s t_a)\frac{S}{4} - c(T_s - T_a) - \sigma T_s^4 (1 - t_a' - a_a') + 2\sigma T_a^4 = 0
\end{aligned}
}
$$

where:

ta – transmission of the atmosphere for short wave radiation

aa – albedo of the atmosphere for short wave radiation

as - surface albedo for short wave radiation

ta'- transmission of the atmosphere for long wave radiation

aa' - albedo of the atmosphere for long wave radiation

Ta - mean temperature of the atmosphere

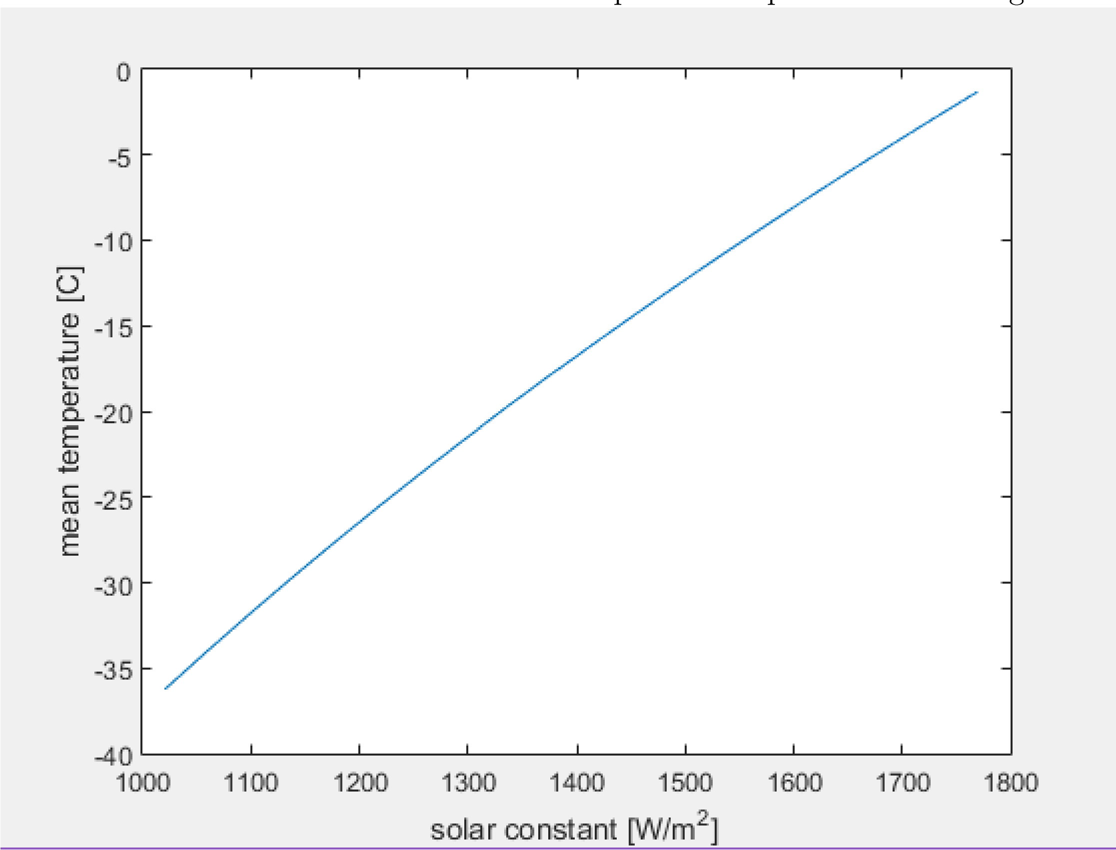
Ts - mean Surface temperature

In this case we are looking for Ta and Ts. In order to observe glacier effect we change albedo of Earth surface to eqaul of ice when temperature is below $-5°C$.

3 Results

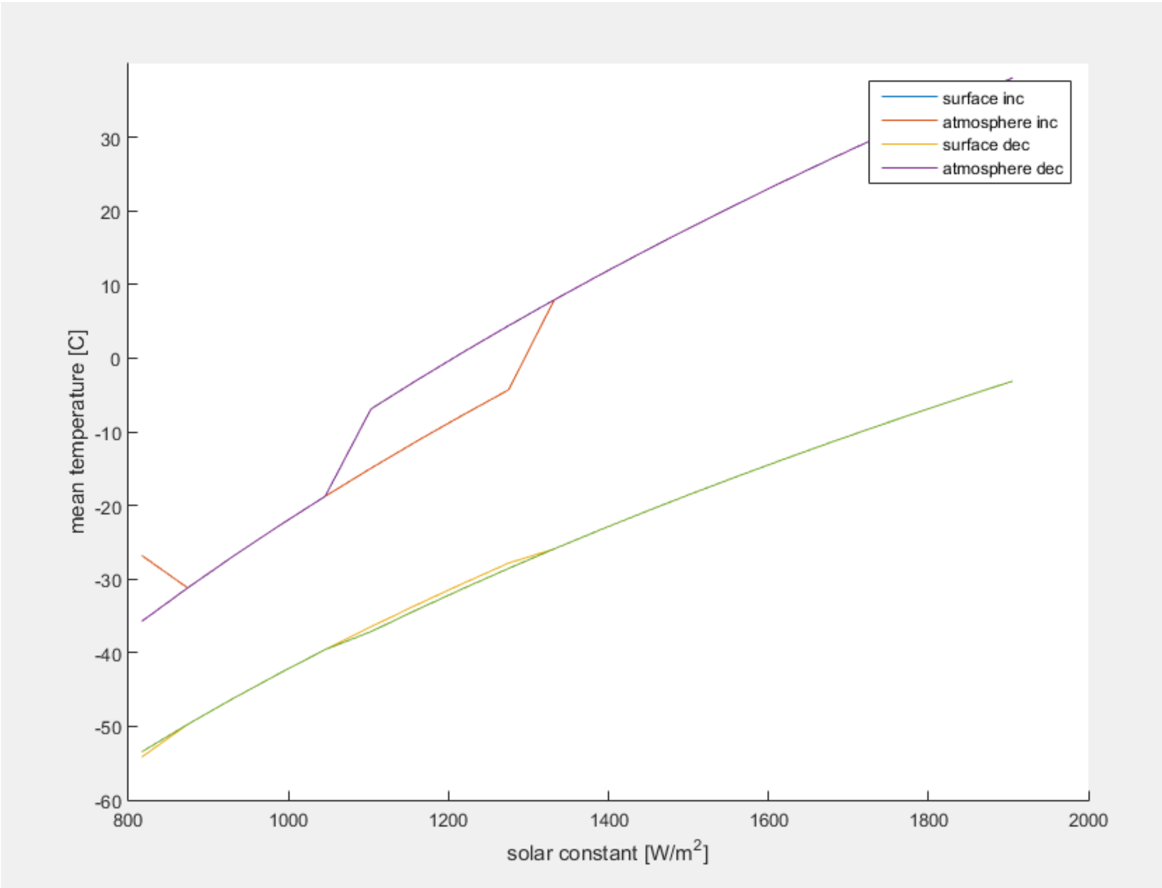
3.1 No Atmosphere

Corelation between solar constant and mean temperature is presented in the figure below.



3.2 With Atmosphere

In the following figure, glacier effect and changes of mean temperature are presented. It is worth to notice that there is a difference depending on a way how solar constant is changing (increments or decreases).



4 Conclusions

This laboratory clearly shows how atmosphere have big influence on the temperature on the surface of Earth. What is more temperature is proportional to solar constant and depends on many factors, for example albedo of surface.

5 Source code

Code contains some parts which were extracted int oanother files in order to achieve better readability.

```
%zad 1
clc;
clear;
```

```
global Pow_z ;
Pow_z = 4 * pi * earthRadius * earthRadius ; %Area of Earth surface
%INPUT DATA
global A ;
A = 0.3; %mean albedo of Earth surface
global sigma ;
sigma = 5.670367 * 1E-8;% Stefan-Boltzman constant

S = 1361; %solar constant

tempForS = meanTempNoAtmosphere(S);

%Check for range of solar constant
S_range = linspace(0.75*S, 1.3*S, 20);

figure(1);
plot(S_range,arrayfun(@meanTempNoAtmosphere,S_range)-273.15);
xlabel('solar constant [W/m^2]');
ylabel('mean temperature [C]');
%Zad 2

global a_s;%surface albedo
a_s = 0.19;
global S_var;
S_var = S;
fun = @meanTempWithAtmosphere;
x0 = [273.15,273.15];

S_range_inc = linspace(0.6*S, 1.4*S,20);
S_range_dec = fliplr(S_range_inc);

surf_inc = [];
surf_dec = [];
atmo_inc= [];
atmo_dec = [];

for i = 1:length(S_range_inc)
    S_var = S_range_inc(i);
    result = fsolve(fun,x0);
    result = result - 273.15;
    surf_inc = [surf_inc ; result(1)];
    atmo_inc = [atmo_inc ; result(2)];
    if result(1)>-5
            a_s=0.3;
    else
```

```
                a_s=0.63;
        end
end

for i = 1:length(S_range_dec)
        S_var = S_range_dec(i);
        result = fsolve(fun,x0);
        result = result - 273.15;
        surf_dec = [surf_dec ; result(1)];
        atmo_dec = [atmo_dec ; result(2)];
        if result(1)>-5
                a_s=0.3;
        else
                a_s=0.63;
        end
end

figure(2);
hold on;

plot(S_range_inc,surf_inc);
plot(S_range_inc,atmo_inc);
plot(S_range_dec,surf_dec);
plot(S_range_dec,atmo_dec);

xlabel('solar constant [W/m^2]');
ylabel('mean temperature [C]');

hold off;
legend('surface inc', 'atmosphere inc','surface dec', 'atmosphere dec');
result = fsolve(fun,x0);
result = result - 273.15;

function F = meanTempWithAtmosphere( X )

global S_var;
S = S_var;
global sigma;

%SHORT WAVE
global a_s;
t_a = 0.53; %transmission of the atmospher
a_a = 0.3; %albedo of the atmosphere
%LONG WAVE
t_a2 = 0.06; %transmission of the atmosphere
a_a2 = 0.31; %albedo of the atmosphere
```

```
c = 2.7;

Ts = X(1);
Ta = X(2);

F(1) = ((-t_a)*(1-a_s)*S/4) + (c * (Ts - Ta)) + (sigma*(Ts^4)*(1-a_a2))-(
    ↪ sigma*(Ta^4));
F(2) = (-(1-a_a-t_a+a_s*t_a)*S/4)-(c*(Ts-Ta))-(sigma*(Ts^4)*(1-t_a2-a_a2)
    ↪ )+(2*sigma*(Ta^4));
end

function [ result ] = meanTempNoAtmosphere( S )
%SET OF ENERGY BALANCE EQUASIONS (no atmosphere):
global Pow_z;
global A;
global sigma;

syms T;
P_sl=S*(Pow_z/4)*(1-A); %Power of solar radiation (short wave)
Pz=sigma*(T^4)*Pow_z; % Power of radiation emitted from Earth (long wave)

eqn = P_sl - Pz == 0;
solution = solve(eqn,T);
%solution(1) - is smaller than 0 REAL
%solution(3) - is not REAL number
%solution(4) - is not REAL number
result = double(solution(2));
end
```