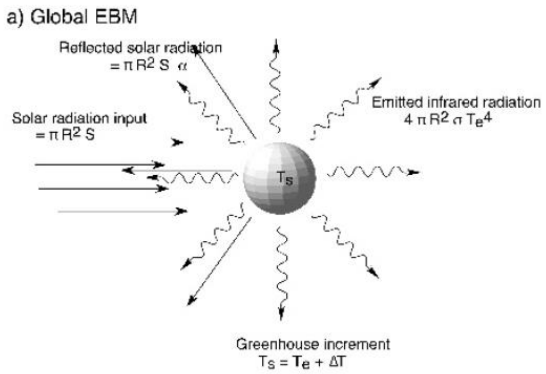
# Laboratory exercise no. 4: Radiation balance of the Earth

Aim: The aim of the laboratory is simulation of the global radiation budget of the Earth.

Laboratory programme:

1. Get acquainted with the simple Earth long-wave and short-wave radiation balance model.
2. Making a simple calculations of mean Earth temperature without atmosphere.
3. Correct calculations for greenhouse effect
4. Writing of the programme code simulating the mean Earth temperature including the atmosphere effect.
5. Calculation of the relationship between mean temperature and solar constant considering the glacial-interglacial transitions.
6. Applying 1D model for comparing climate switching points




**Set of energy balance equations (no atmosphere):**

$$P_{Sł} = S \cdot \frac{Pow_Z}{4} \cdot (1 - A)$$

$$P_Z = \sigma \cdot T^4 \cdot Pow_Z$$

$$P_Z = P_{Sł}$$

where:

$P_{Sł}$ – 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 Earth
$\sigma$ -Stefan-Boltzmann constant

Try to modify long wave component to correct results for greenhouse effect.

**Set of energy balance equations (with atmosphere):**

$$(-t_a)(1-a_s)\frac{S}{4}+c(T_s-T_a)+\sigma T_s^4(1-a_a^{'})-\sigma T_a^4=0$$

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

where:

- $t_a$ – transmission of the atmosphere for short wave radiation
- $a_a$ – albedo of the atmosphere for short wave radiation
- $a_s$- surface albedo for short wave radiation
- $t_a$'- transmission of the atmosphere for long wave radiation
- $a_a$'- albedo of the atmosphere for long wave radiation
- $T_a$- mean temperature of the atmosphere
- $T_s$- mean Surface temperature

Input data:

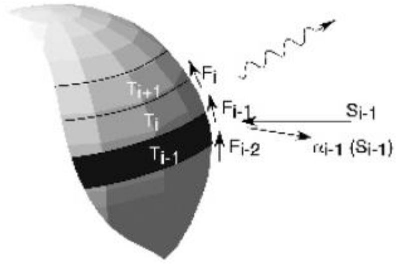
for version 1:

A=0.3 S=1366 W/m$^2$ $\sigma$=5.67x10$^{-8}$ W/m$^2$K$^4$

for version 2:

| Short wave radiation | Long wave radiation |
|---|---|
| $a_s$=0.19<br>$t_a$=0.53<br>$a_a$=0.30 | $t_a^{'}$=0.06<br>$a_a^{'}$=0.31 |
| c=2.7 Wm$^{-2}$K$^{-1}$<br>Solar constant range 0.8 to 1.2 S | |

b) One-dimensional EBM



**One dimensional energy balance**

Energy balance is calculated according to formula:

$$S_i(1-\alpha(T_i)) = R\uparrow(T_i) + F(T_i)$$

Where:
Si – Short radiation energy flux for I latitudinal band
$\alpha$ - albedo
Ti – Temperature of latitudinal band
R – long wave radiation flux (linearized and corrected for greenhouse effect)
F – heat exchange between bands

Albedo is defined for each band separately, and if temperature of band is below critical value, ice albedo is assigned for such band.
Long wave radiation is parametrized using linear function having parameters A=204 W/m$^2$ and B=2.17 W/m$^2$degC.

$$R_i \equiv R\uparrow(T_i) = A + BT_i$$

Where:
Temperature is expressed in degC

Heat transfer between bands is proportional to difference between band temperature and mean temperature of the planet.

$$F_i \equiv F(T_i) = k_t(T_i - \overline{T})$$

Where:
Kt – constant empirical value assigned in the model as C=3.81 W/m$^2$degC

Laboratory outline:

1. Performing of simple calculation of mean Earth temperature assuming no atmosphere
2. Writing the programme code solving set of nonlinear equations.
3. Calculation of relationship between mean temperature and solar constant
4. Comparison of the results
5. Implementation of glaciations mechanism in the model ( Surface albedo depend on the temperature).
6. Calculation of solar constant values associated with glacial-interglacial transition of the Earth system.
7. Comparison of results obtained in point 6 with 1D model available to download at the webpage.
8. Computer programme can be written in any programming language or software environment. Recommended environment is MATLAB.
9. Programme code supplemented with appropriate comments should be included as a part of a report prepared in pdf format.
10. The report must include the conclusion.

References:

Kendal McGuffie and Ann Henderson-Sellers, A Climate Modelling Primer, John Willey & Sons, Ltd 2005 ISBN: 0-470-85751