1. **Simple Box model** (*6 points*)

   The stability of the AMOC is studied in a simple box model.

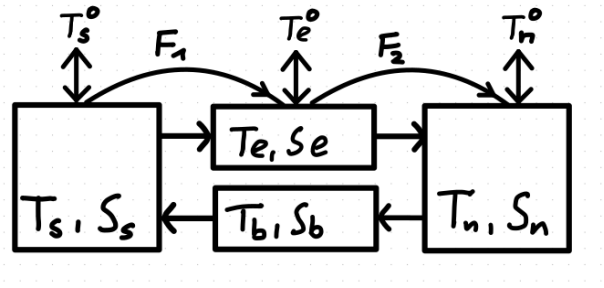

Figure 1: Sketch of the simple box model of the Atlantic Overturning. F_1 and F_2 denote the freshwater transport in the atmosphere at the interfaces of the ocean boxes.

   Use the python program (here)

   a) Show that the stability of the AMOC depends on F_1 and not on F_2.

   b) Evaluate the importance of the high latitude temperatures on AMOC, and on AMOC's stability.

   c) Calculate a hysteresis for a control parameter of the model. Discuss your results!

2. **EBM on the computer** *(6 points)*

   Go to the

   EBM web site

   or EBM web site2

   Answer the following for both models:

   a) What will happen if the CO_2 content in the atmosphere is doubled? Radiative forcing for doubling of $CO_2 = 4W/m^2$. The easiest way is to lower the parameter A in equation (1).

   b) Describe the effect if the diffusivity is enhanced by a factor of 2!

   c) The coalbedo of sea ice can vary. Describe the effect when enhancing the value by 0.1!

3. **Analytical EBM** *(4 points)*

   The temperature is described as $T(y)$ and the heat transport (sensible, latent and ocean) is modelled as diffusion:

$$C_p\,\partial_t T \;+\; k\,\partial_y^2 T \;=\; (1-\alpha)Q_S^{top} - (A + B\;T) \tag{1}$$

   Show the solution if the planetary albedo α is chosen as a constant parameter. Use the ansatz with a global component and a latitude component

$$T(y,t) \;=\; T_0(t) + T_1(t)\cdot\cos\left(\frac{2\,y}{R}\right) \tag{2}$$

$$Q_S^{top} \;=\; Q_0 + Q_1\cdot\cos\left(\frac{2\,y}{R}\right) \tag{3}$$

   with $y = R\varphi$, R is the Earth radius, φ the latitude.

   Separate the dynamics for T_0 and T_1.

Notes on submission form of the exercises: *Working in study groups is encouraged, but each student is responsible for his/her own solution. The answers to the questions can be send until the due date (12:00 pm) to Alessandro Gagliardi (Alessandro.Gagliardi@awi.de), Georg Huettner (Georg.Huettner@awi.de).*