Dynamics 2 | Exercise 6, Summer Semester 2021
Lecturer: Prof. Dr. G. Lohmann | Tutors: Justus Contzen, Lars Ackermann
Due date: 07.06.2019 | 31.5.2021

Motivation: Paleoclimatic evidence suggests that some past climate shifts were associated with changes in North Atlantic Deep Water (NADW) formation. Deep water formation in the Greenland-Iceland-Norwegian Sea and in Labrador Sea drive the large-scale ocean circulation imposing strong northward heat transport. This makes the northern North Atlantic about 4-10 K warmer than corresponding latitudes in the Pacific and is responsible for the mild climate of Western Europe. Variations in NADW circulation therefore have the potential to cause significant climate change in the North Atlantic region.

The following questions are related to the box model (3 points each):

1. In the regions of deep water formation in the North Atlantic, relatively small amounts of fresh water added to the surface can stabilize the water column to the extent that convection can be prevented from occurring. Such interruption decreases the poleward oceanic mass transport Φ. Furthermore, this perturbation of the meridional transport can be amplified by positive feedbacks: a weaker northward salt transport brings less dense water to high latitudes, which further reduces the high-latitude density. Discuss the case where the initial conditions in salinity at different latitudes is changed.

   Show this scenario in the box model by adding freshwater to the high-latitude northern box!

2. Comment on the scenario of climate change as shown in the cinema movie The Day After Tomorrow: link to the website or go to the trailer.

3. Which feedbacks are acting for global warming? You can change the long wave radiation. A doubling of pCO_2 is equivalent to an additional forcing of 4 Wm^{-2}. For this you have to modify the net radiation balance through reduction in the outgoing longwave radiation (parameter γ). Additional radiative forcing may come from increased tracer gas concentrations in the atmosphere. Please evaluate the hydrological cycle and atmospheric heat transports! What is the change in the overturning rate?

4. Change the ocean heat capacity by a factor of 10 and describe the change in the response to warming induced by 90% of the longwave radiation.

5. The initial values of the model represent averages for present-day climate conditions. Can you derive a glacial climate? The glacial climate was 3 K colder in the tropics.

6. Calculate the ocean heat transport in the model and compare it with the following

estimate!

$$H = \int_{bottom}^{top} \rho_0 v T dz \quad (1)$$

$$= -c_p \int_{bottom}^{top} \frac{\partial \Phi}{\partial z} \quad T dz \quad (2)$$

$$= c_p \int_{bottom}^{top} \Phi \quad \frac{\partial T}{\partial z} dz \quad (3)$$

$$= c_p \int_{T(bottom)}^{T(top)} \quad \Phi dT \quad (4)$$

where $\Phi = \rho_0 \Phi_{MOC}$ with Φ_{MOC} being the volume transport. Therefore, the heat transport can be estimated in terms of the mass transport in temperature layers:

$$H = c_p \underbrace{(T(top) - T(bottom))}_{15K} \quad \underbrace{\Phi_{max}}_{20 \cdot 10^9 kg/s} \quad (5)$$

which is about 1.2 $PW (PW = 10^{15} W)$.

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) to Justus Contzen (Justus.Contzen@awi.de), Lars Ackermann (Lars.Ackermann@awi.de).*