1. Introduction

Motivation: Salt is a crucial component of sea ice since it determines many of the ice’s physical and biogeochemical properties. Salt that is rejected from sea ice into the underlying ocean has an impact on the stability of the oceanic mixed layer and consequently also on the global ocean circulation. Despite this importance, the temporal evolution of the sea-ice salinity and the salt release into the underlying ocean are still only poorly represented in numerical climate models.

Approach: To improve the sea-ice representation in climate models we have developed a new one-dimensional thermodynamic model that allows us to simulate the salinity evolution of sea ice.

Questions we address:
1. Can the relevant desalination processes be parametrized in a one-dimensional model?
2. Can we reproduce lab experiments?
3. Can we realistically reproduce sea ice over multi-year timescales?
4. Can this be achieved at reasonable computational cost?

2. Model Description

Multi-phase enthalpy approach: Each layer of our 1-D sea-ice model is represented by its enthalpy, bulk salinity, mass, and thickness (H, S, m & h). All other quantities (such as the relative fractions of solid, liquid and gas) are derived from the four state variables.

Layout: Figure 2.1. indicates how the layers are arranged. The number of layers varies between one and an adjustable parameter N depending on ice thickness. Solid and liquid precipitation create a saltless snow layer while a mostly liquid bottom layer interacts with the ocean.

Model Forcing: The surface temperature is determined by balancing incoming short and longwave radiation with outgoing longwave radiation and heat transport in the top layer. The ocean heat fluxes are either assigned or based on the temperature distribution.

3. Desalination Processes

3.1. Gravity Drainage

Gravity drainage (the exchange of cold, dense brine leaving the ice with fresher seawater) has been shown to be the most important desalination process. We have parameterized gravity drainage (which occurs mainly during bottom growth and to a lesser extent during bottom melt) into our one-dimensional model by means of a Rayleigh number Ra. We set $\beta_i = \alpha (R_b - R_{mon})$ and mass conservation results in $\beta_i = \sum_{i=1}^{N} \beta_i$. This approach is derived from the results of Wells et al. PRL 2010. The Rayleigh number of the layer $i$ $(\beta_i, \Delta b_i, \Delta l_i)$ describes the ratio of buoyancy to dissipation and is a function of the brine salinity $S_{br}$, the distance to the ice bottom $\Delta h$ and the permeability $\Pi$ which is itself a function of the liquid fraction $\psi$. We tune the two free parameters $\alpha$ and $R_{mon}$ to reproduce the lab data shown in figure 5.1.

Figure 3.1. Brine leaves the ice through brine channels and is replaced by water that seeps upward through interstitial pore space.

4. Test Runs

a) To evaluate the long term behavior we present two 4.5 year long test runs starting on the 1st of July 2005. Incoming radiation and precipitation are taken from ERA-interim reanalysis data and the oceanic heat flux is a prescribed annual cycle. b) $x [m]$ $T$ $\Psi$ $[\%]$ $[\degree C]$ $S_{br}$ [psu]

5. Comparison to Lab Experiments

We used lab data attained by Notz (2005) to tune and verify our parametrization of gravity drainage. The experiment provided salinity measurements at different height levels of a tank which was cooled from above over 72 hours by a cooling plate. Although the results surpass our expectations, we hope to soon have additional data of growth and melt over longer time periods to add confidence and to study flushing. $S_{br}$ [psu]

Figure 4.1. Non-liquid volume fraction $\Psi$, temperature $T$ and bulk salinity $S_{br}$ over 4.5 years. The dashed lines indicate the snow-ice boundary.

4.1. Multi-year sea ice

Noteworthy features include the sudden gravity drainage due to a warming at t=6 years, and the lack of flushing after years 2 and 3 due to impermeable top ice layers.

Figure 4.2 Experiments...

6. Conclusions

6.1. Results

- The gravity-drainage parametrization provides results which are in good agreement with measured lab data.
- Multi-year test runs can not be evaluated against measurements but show promising results at reasonable computational cost.
- Lack of frazil ice, turbulence and other dynamic processes not included in the 1D model hinder realistic formation of sea-ice.

6.2. Outlook

- Gather additional salinity time-series measurements to evaluate and further refine the desalination parametrizations.
- Expand the new thermodynamic model to take frazil and grease ice formation into account.
- Conduct first tests using a coupled GCM.

4.2. Seasonal sea ice

Noteworthy are the strong flooding events at warmer temperatures and rain lead to flushing during the growth phase. This effect may be reduced by turbulent frazil ice...