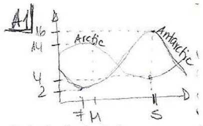
A1



A2 MIZ: Zone zw. Eis und offenem Ozean, Interaktion mit Wellen, Strahlung, gr. biologische Aktivität

Fast ice: near islands/coast, angedockt an Küsten oder am Boden, bewegt sich nicht

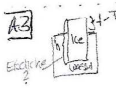
Shear zone: Zone zw. Driftice und Fastice (oder Küste), Deformation und shear (many ridges)

Perennial ice: Zone, die mind. 1 Jahr mit Eis bedeckt ist

Polynya: Gebiet mit dünnem Eis oder offenem Wasser, Eis wird geöffnet durch
- wind (coastal polynya)
- upwelling (~~latent~~ sensible-heat-polynya)

Lead: lineare Öffnung im Eis, 10m breit, Entstehung: durch Deformation

A3



$h(\rho_w, f, \rho_{ice}) = ?$

$h = \frac{1}{1-\frac{\rho_{ice}}{\rho_w}}$

$\rho_{fyi} = 910\ kg/m^3$

$\rho_{myi} = 887\ kg/m^3$

$\rho_w = 1023\ kg/m^3$

A4 a) Energie, um 1 kg Eis bei T=0°C zu schmelzen (L=330 J/g)

$\Delta Q = m \cdot L = 330\ kJ$

b) T = ?, wenn Wasser (T=0°C) mit dieser Energie erhitzt wird

$\Delta Q = c_p \Delta T \cdot m$ (← ges.), $c_p = 400\ J/kgK$

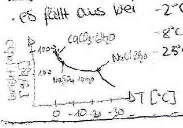
A5 Sea ice growth, Freezing in 1 Tag

$\Delta Q = m \cdot L = L\rho V = L\rho HA$

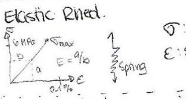
$\frac{\Delta Q}{tA} = F = \frac{L\rho HA}{tA} = \frac{L\rho H}{t} \Rightarrow H = \frac{Ft}{L\rho}$

A6 Sea ice phase diagram

- es fällt aus bei -2°C: $CaCO_3 \cdot 6H_2O$ — hydrierte Form des Salzes
- -8°C: $Na_2SO_4 \cdot 10H_2O$
- -23°C: $NaCl \cdot 2H_2O$



Elastic Rheol.

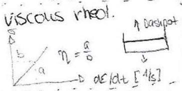


σ: Stress = F/A

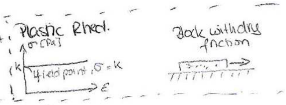
ε: Strain = $\Delta L / L$

$\frac{d\varepsilon}{dt}$: strain rate

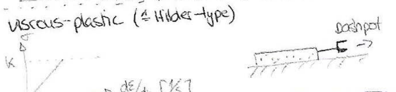
Viscous rheol.



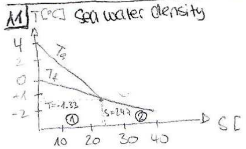
Plastic Rheol.



Viscous-plastic (≙ Hibler-type)



A1 Sea water density



① Surface cooling creates stable vertical density profile

② Surface cooling creates unstable vertical density profile → convective mixing

A2 Sea ice growth, Lebedev: $d = 1.33\,\theta^{0.58}$

$\theta = \int_0^t (T_f - T_a)\,dt$

- $T_f = -2°C$, $T_{a1} = -10°C$, $T_{a2} = -20°C$, $\theta_1 = 8°C$, $\theta_2 = 18°C$, d_1 4.6 cm, $d_2 = 7.4\ cm$

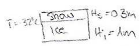
A3 Conductive heat flux

$F_c = \frac{k}{H}(\Delta T)$, $H_1 = 0.1\ m$, $H_2 = 1\ m$, $k_{ice} = 2.1$

$F_{c1} = \frac{2.1}{0.1}(-30) = -630\ W/m^2$

$F_{c2} = -63\ W/m^2$

b) 2 Layers, $k_s = 0.2\ W/mK$



$F_c = \left(\frac{H_1}{k_1} + \frac{H_2}{k_2}\right)^{-1} \cdot (\Delta T) = -15.2\ W/m^2$

A4 Brine Salinity

Discontinuities
- Salt at -8°C: Sodium Sulfate Na_2SO_4
- Salt at -23°C: Sodium Chlorid NaCl
- Salinity of the liquid brine is only a function of the temperature, because of the Gibbs phase rule!

$F = C + 1 - P$ — C: 2 components; 2 Salts

$F = 2 + 1 - 2 = 1$ — P: Number of Phases = 2

- 1 degree of freedom ≙ Temperature

Polynyas

1) open-O. P.: sensible heat polynya, driven by convection / upwelling, heat loss goes into cooling of water column
   coastal P.: driven by offshore winds, heat loss goes into ice growth, latent heat polynya
2) NH: most are coastal (Bering-, Okhotsk-, Barents Sea), only open-O.-P. → Kashevarov Bank-P. (Okhotsk)
   SH: mostly open-o. P. (2-3 coastal), at Ronne-, Amery-, Ross Ice Shelves (e.g. Mertz Ice Tongue P.), form at lee-side of islands, grounded ice bergs
3.) Antarctic: 10 m/season (ice thickness)
4.) freezing can occur in the entire water column → Sediments from bottom and water column are included into ice and through convection transported to surface, then drifted away
5.) vital for most species in region
   - early ice-freeness in spring → more sunlight → increase of primary production
   - whale migration routes
   - summer habitat for marine birds and mammals
6.) ~~big p~~ influence on Arctic: big producer of ice + brine, convection + cooling of bottom water, gas exchange, biolog. importance
7.) Balance of ice production rate + advection away from coast (e.g. wind) → maximum width
8.) Formation of new ice is more important than wind speed → Temp > wind speed

A1 Radiative fluxes
- shortwave radiation: $\lambda_{max} = 0.5\ \mu m$ (von Sonne)
- longwave rad.: $\lambda_{max} = \sim 12\ \mu$ (von Erde)
- center wavelength = λ_{max} of short/longwave
- Trennung möglich, da sich nur ein kleiner Teil überlagert

A2 Earth's radiative energy budget
- Jan: 351.71 W/m^2
- Juli: 329.63 W/m^2
- zonal averaged maximum (Juni): am Nordpol < 500 W/m^2

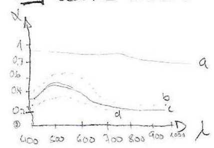
A3 radiative energy balance - snowball earth

$(1-\alpha) S = \sigma \varepsilon T^4$

$T = \sqrt[4]{\frac{(1-\alpha)S}{\sigma}}$

- α: Albedo
- S: solar irradiance
- σ: St.-Boltzm. $5.67 \cdot 10^{-8}\ W m^{-2} K^{-4}$
- ε: therm. emissivity: 1 (black body)

A4 Sea ice albedo



- a: snow covered ice (dry snow)
- b: young melt pond
- c: mature melt pond
- d: — " —

α	clear	mit Wolken	alle
dry snow w/o(ice)	0.63	0.77	~0.8
melt pond (mature	0.22	0.29	~0.2

mit Eis bedeckt: ~0.4

A5 Thermal emission

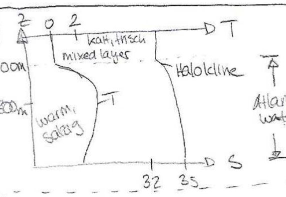
$F = \varepsilon \sigma T_0^4$ — F: heat flux

A6 Cloud radiative forcing

$F = \varepsilon \sigma T_0^4$

$\varepsilon = 0.7855(1 + 0.2232\,C^{2.75})$ ← cloud coverage (clear: C = 0, cloud: C = 1)

A1



- mixed layer am Gefrierpunkt

A2 Equilibrium sea ice thickness + ocean heat flux

$F = \frac{k}{d} \Delta T$

reziproke Addition $\frac{d}{k} = \frac{d_s}{k_s} + \frac{d_i}{k_i}$ ← gesucht

$d_i = \left(\frac{\Delta T}{F} - \frac{d_s}{k_s}\right) k_i = 0.462\ m$ (with $\frac{\Delta T}{F} > 0$)

Skript steady state ice drift velocity

$\vec{\tau}_w = \vec{\tau}_a$

$\rho_w C_{dw} |\vec{v} - \vec{v}_w| (\vec{v} - \vec{v}_w) = \rho_a C_{da} |\vec{v}_a| \vec{v}_a$ (with $\vec{v}_w \to 0$)

$\vec{v}_w = 0$, da Ozean in Ruhe

$\vec{v} = v_a \sqrt{\frac{\rho_a C_{da}}{\rho_w C_{dw}}} \approx 0.02 \cdot v_a$