EBM with sea ice

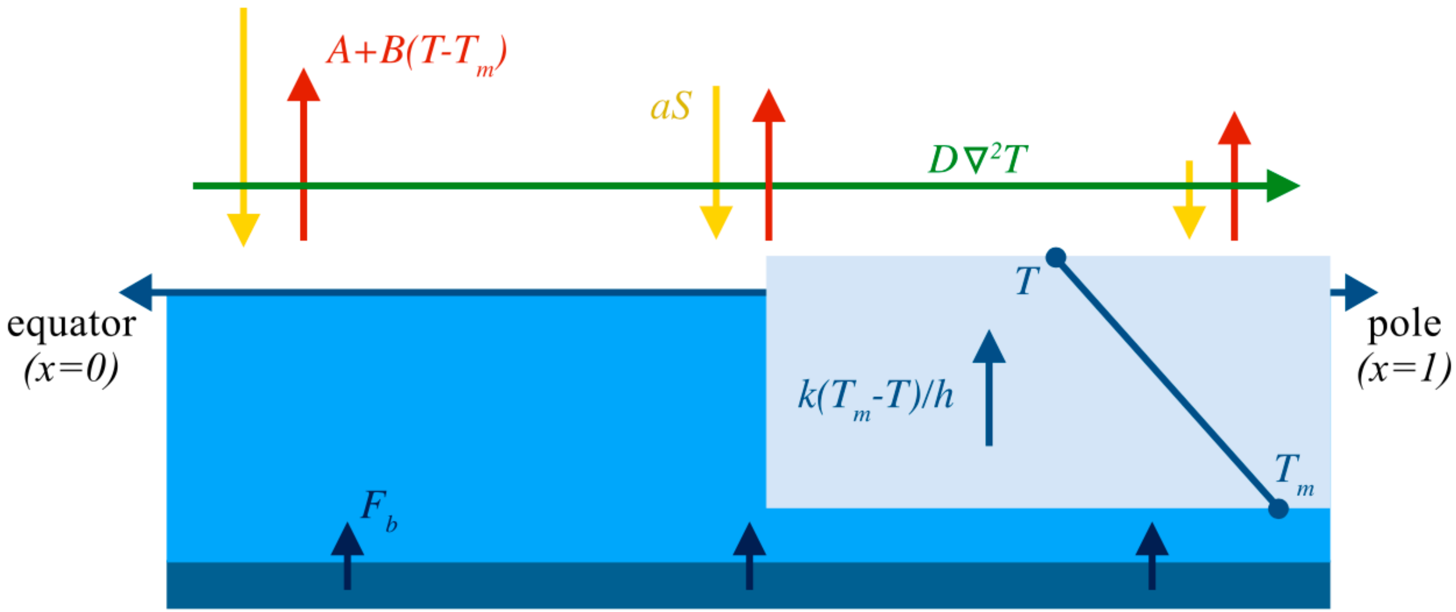

FIG. 1. Schematic of the global model of climate and sea ice described in section 2, showing the fluxes included in the model: insolation (yellow), OLR (red), horizontal heat transport (green), ocean heating (dark blue), and vertical heat flux through the ice (blue). The temperature of the ice is given by T at the surface and T_m at the base.

How Climate Model Complexity Influences Sea Ice Stability
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The equations

$$\frac{\partial E}{\partial t} = \underbrace{aS}_{\text{solar}} - \underbrace{L}_{\text{OLR}} + \underbrace{D\nabla^2 T}_{\text{transport}} + \underbrace{F_b}_{\substack{\text{ocean}\\ \text{heating}}} + \underbrace{F}_{\text{forcing}}$$

$$E \equiv \begin{cases} -L_f h, & E < 0 \quad \text{(sea ice)}, \\ c_w (T - T_m), & E \geq 0 \quad \text{(open water)}, \end{cases}$$

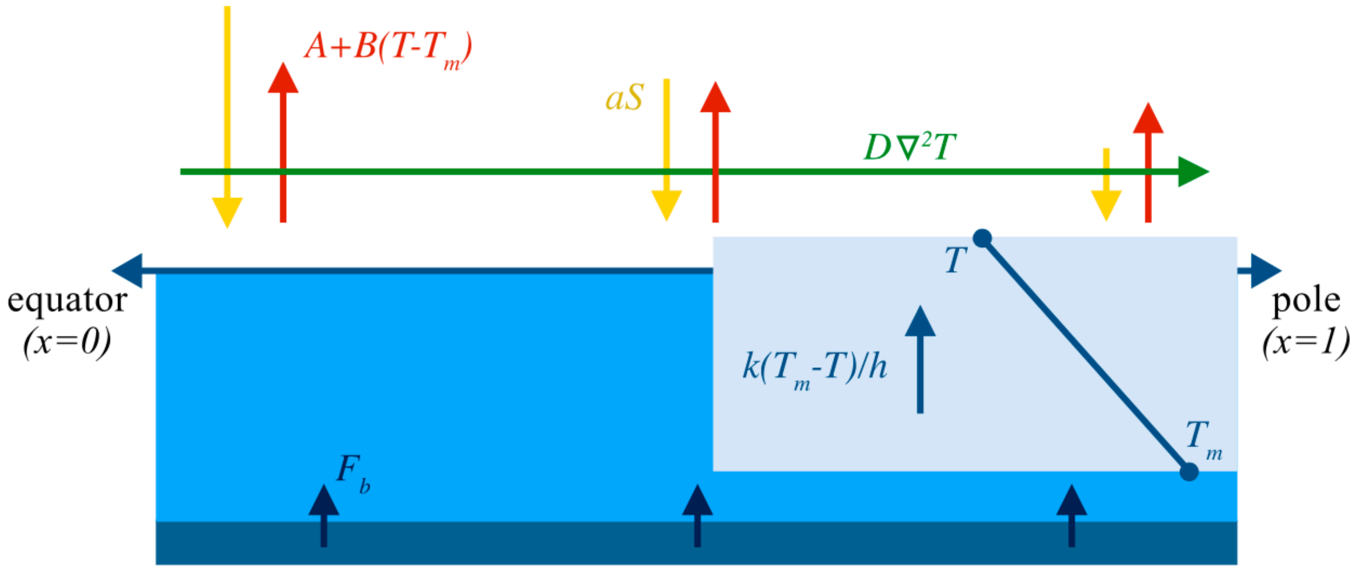
$$S(t, x) = S_0 - S_1 x \cos\omega t - S_2 x^2$$

$$a(x, E) = \begin{cases} a_0 - a_2 x^2, & E > 0 \quad \text{(open water)}, \\ a_i, & E < 0 \quad \text{(ice)}, \end{cases}$$

$$D\nabla^2 T = D \frac{\partial}{\partial x}\left[(1 - x^2)\frac{\partial T}{\partial x}\right]$$

$$L = A + B(T - T_m)$$

EBM with sea ice



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$$k(T_m - T_0)/h = -aS + A + B(T_0 - T_m) - D\nabla^2 T - F$$

$$T = \begin{cases} T_m + E/c_w, & E > 0 & & \text{(open water)}, \\ T_m, & E < 0, & T_0 > T_m & \text{(melting ice)}, \\ T_0, & E < 0, & T_0 < T_m & \text{(freezing ice)}. \end{cases}$$

output

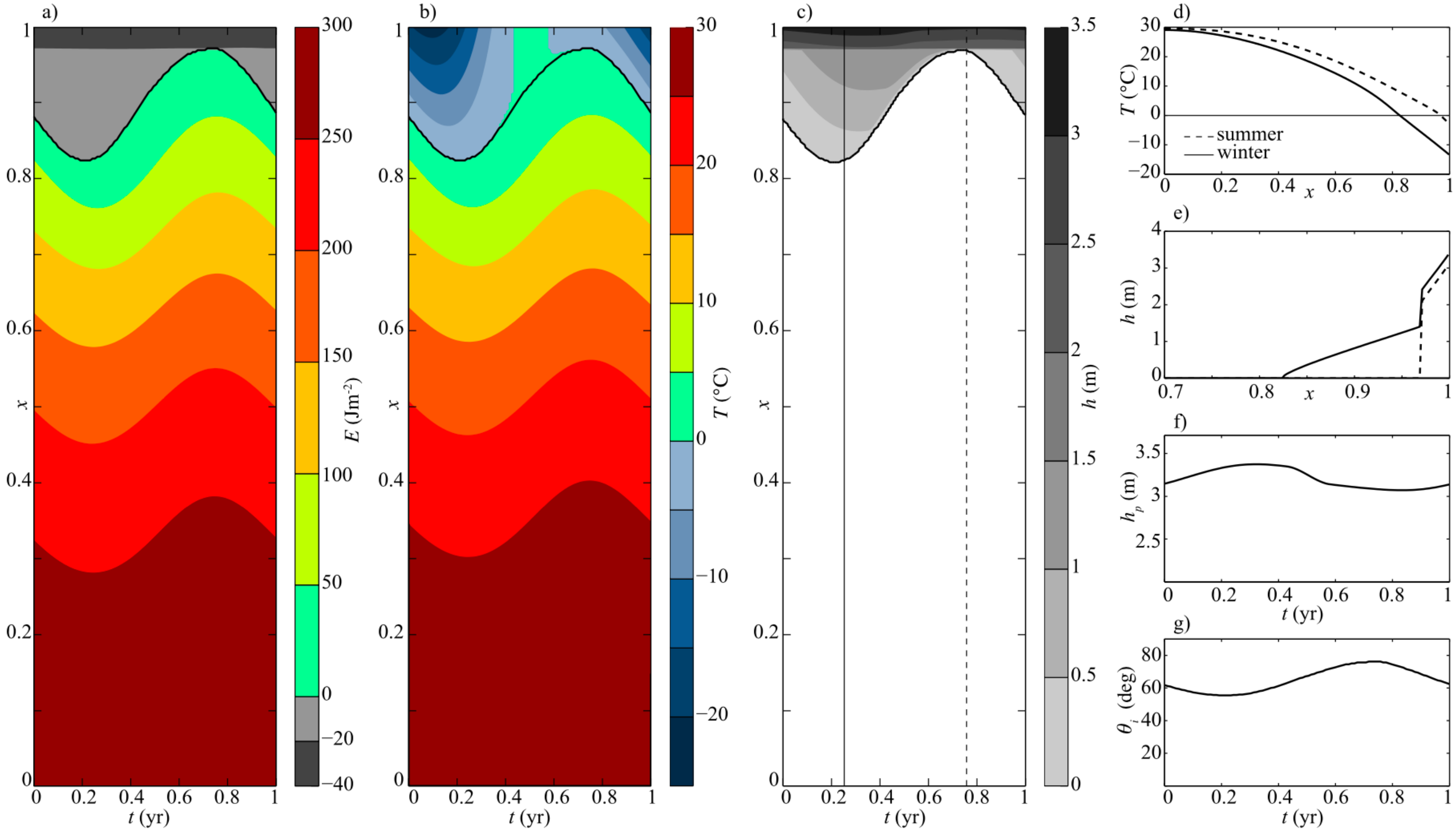

FIG. 2. Simulated climate in the default parameter regime. Contour plot of the seasonal cycle of (a) surface enthalpy $E(x, t)$, (b) surface temperature $T(x, t)$, and (c) sea ice thickness $h(x, t)$. The black curve in (a)–(c) indicates the ice edge. (d) Surface temperature T in summer and winter, corresponding to dashed and solid vertical lines in (c). (e) Ice thickness h in summer and winter where $x > 0.7$. (f) Seasonal cycle of ice thickness at the pole h_p. (g) Seasonal cycle of the latitude of the sea ice edge θ_i.

Exercise: EBM (upper Model)

$D* = Wm^{-2}K^{-1}$ Diffusivity for heat transport: 0.6

$A = Wm^{-2}$ OLR:193

$B = Wm^{-2}K^{-1}$ OLR temperature dependence: 2.1

$cw = Wyrm^{-2}K^{-1}$ Ocean mixed layer heat capacity: 9.8

$S0 = Wm^{-2}$ Insolation at equator: 420

$S2 = Wm^{-2}$ Insolation spatial dependence: 240

A0 Ice-free coalbedo at equator: 0.7

A2 Ice-free coalbedo spatial dependence: 0.1

Ai Coalbedo when there is sea ice: 0.4

Wm^{-2} Radiative forcing: 0

γ Gamma: 1

1) What will happen if the CO_2 content in the atmosphere is doubled? Radiative forcing= 4 Wm-2
2) What will happen if the factor γ is 1% higher/lower in the long-wave radiation?
3) Describe the effect if the diffusivity is enhanced by a factor of 2!
4) The coalbedo of sea ice can vary between 0.3 and 0.4. Describe the effect when varying the value!
5) Write down the numerical scheme (time stepping etc. from the source code) !
6) Show the evolution at one specific latitude and discuss it!

Exercise:
Aquaplanet EBM with seasonal cycle (lower model)

1) What will happen if the CO_2 content in the atmosphere is doubled?
   (Radiative forcing= 4 Wm^{-2}= lowering of A)

2) Discuss the sea ice evolution during the year !

3) Reduce (enhance) the sea ice thermal conductivity by 20% mimiking more (less) snow on top of sea ice !

4) Write down the numerical scheme (time stepping) !