Miniproject # 1 for ATSC 409: Arctic Ocean Near Surface Temperature Maximum

Consider summer in the Arctic Ocean (Canada Basin). The surface of the ocean is partially covered by ice (say ice fraction β). The sun is bright (assume no clouds) and shines most of the day (assume all day). Take an incoming radiative flux of 100 W m^{-2}, a water albedo of 0.1 and assume that no light penetrates through the ice-covered portion (i.e. it has lots of snow on top). Ice is melting, and so the surface temperature is the freezing temperature of salty water, say -1^{o}C. Deep in the water column, at 200 m depth, the temperature is -2^{o}C. The light energy I decays exponentially with depth with an e-folding scale of α.

In the polar ocean, density is determined by salinity.[1] The surface layer of the ocean of depth (h) is well-mixed and relatively fresh. Below that is a strongly stratified layer and then less stratified water. Assume an eddy-viscosity or mixing coefficient (A_h) of the form

$$A_{max}, \quad d < h \tag{1}$$

$$A_{depth} + [A_{max} - A_{depth} - A_{dip}(d-h)] \exp\left[-0.5(d-h)\right], \quad d > h. \tag{2}$$

where d is the depth, positive in the ocean, measured down from the surface.

An equation for the temperature T as a function of depth, d is

$$\frac{\partial T}{\partial t} = \frac{\partial}{\partial d}\left(A_h \frac{\partial T}{\partial d}\right) - \frac{1}{c_p}\frac{\partial I}{\partial d} \tag{3}$$

where $c_p = 4000\text{J kg}^{-1}\ {}^o\text{C}^{-1} = 4 \times 10^6\text{J m}^{-3}\ {}^o\text{C}^{-1}$ is specific heat.

Assume steady state and explore the temperature profiles for various ice concentrations β, mixing profiles(make sure your A_h does not go negative), light attenuation rates (α).

Starting parameter suggestions: $\beta = 0.5$, $\alpha = 1/(10\text{ m})$, $h = 10$ m, $A_{max} = 1 \times 10^{-2}\text{m}^2\text{s}^{-1}$, $A_{depth} = 1\times10^{-4}\text{m}^2\text{s}^{-1}$, and $A_{dip} = 1.5\times10^{-3}\text{m}^2\text{s}^{-1}$. These should give you a Near Surface Temperature Maximum (NSTM) — see Figure 2 of Jackson et al. https://circle.ubc.ca/handle/2429/34555 but note that the vertical axis is a logscale.

Hand-In:
p = on paper
e = electronic (email to sallen@eos.ubc.ca)
pe = either paper or electronic pdf files
Or you can do it all in a python notebook

p Derivation of the equations you put into your computer model.

p A paragraph discussing the method of solution.

e Your code

pe Results of the base case and your variations (graphs, summary tables)

p A discussion of the results of your variations

[1] Which means its perfectly possible to have colder water above warmer water