Lab Week 10 – Sea Ice Production and Melt

Sea Ice Thermodynamics

Sea ice will grow or shrink depending on the energy balance at the base of the sea ice. Conductive transfer of heat energy is critical as a means of (a) evacuating the heat produced in the ocean so it doesn't build up in the ice and (b) removing the energy released as latent heat during freezing. To calculate the freezing rate of ice, you must first calculate the total heat energy leaving the bottom of the sea ice column.

Some Assumptions and hints to keep in mind:

1) The system is in thermodynamic equilibrium. The means that the amount of energy entering the base of the ice column must be equal to the energy being conducted to the atmosphere.
2) The base of the ice column is at the mean mixed-layer ocean temperature. The surface of the ice is at the air temperature. The energy input to the surface is negligible (i.e., it is a clear, polar night).
3) Any difference in the amount of heat being conducted out into the atmosphere and the amount of heat produced in the ocean water must (i) be melting the basal ice or (ii) be generated by the freezing of basal ice.

Some parameter values for your use:

Air Temperature:	-21.5°C	*Seconds per Year:*	3.154e7
Freezing Temp (Sea Water):	-1.5°C	*Thermal Conductivity (Sea Ice):*	1.5 W/(m°C)
Latent Heat of Fusion:	331,000 J/kg	*Thermal Conductivity (Snow):*	0.2 W/(m°C)
Density of Ice:	917 kg/m^3	*Ocean Heat Production:*	15 W/m^2

Problem 1 – First Year Sea Ice:

You want to predict what sea ice thickness in the Beaufort Sea will be at the start of Arctic Summer, based on the climate variables and thermodynamic properties of ice listed above. A good first guess at the thickness is the equilibrium sea ice thickness – the thickness of ice that results in heat conduction exactly equal to the heat produced in the ocean.

a) Compute the equilibrium sea ice thickness for the Beaufort Sea.
b) You find a slab of sea ice that is presently 0.8m thick. What is the sea-ice growth rate at the base of this slab (in cm/day)? Would the growth rate be faster or slower if the slab were 1m thick?

Problem 2 – Snow Covered Sea Ice:

Now, 0.2m of snow fall on the sea ice surface. What is the new equilibrium sea ice thickness? What was the net effect of this new snowfall on the energy balance?