

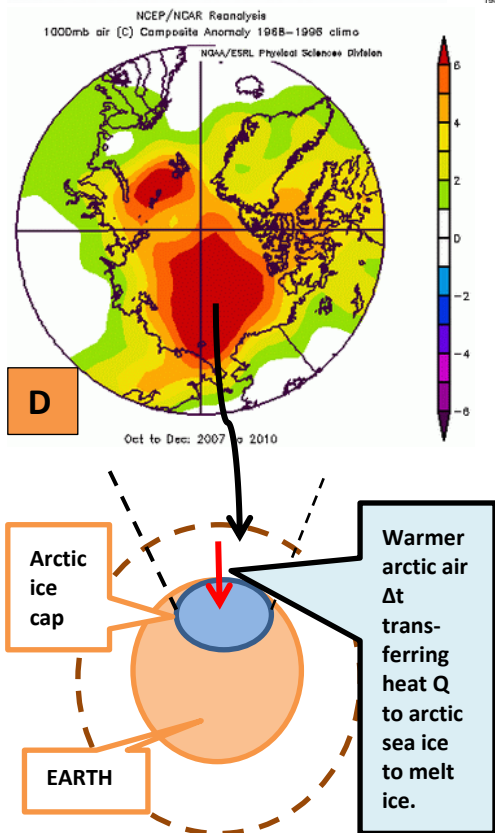
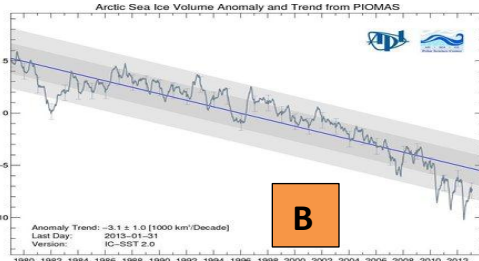
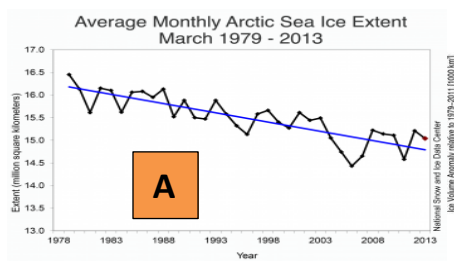
HEAT

Arctic ice melt = $-3.1 \times 10^3 \text{ km}^3/\text{decade}$ Units 20 Dr. John P. Cise, Professor of Physics,

Austin Community College, 1212 Rio Grande St., Austin Tx 78701 & NYTimes April 20, 2013 by NYTimes Editorial Board

Reaching an Arctic Accord

The **central Arctic Ocean** has been covered in ice for eons, **but under the influence of global warming, (((nearly half of it is now open water))) for part of the year.** Commercial fishing has not yet begun there, but the urge to begin fishing is almost overwhelming. The **waters of the central Arctic, an area the size of the Mediterranean,** hold the last untouched fishing stocks on this planet. At present, they also lie beyond the boundaries of settled international law — more than a million square miles outside the reach of the exclusive economic zones that protect the national waters of the five countries with coastlines on the Arctic: the United States, Russia, Canada, Denmark and Norway. What ice once protected, it is now up to humans to protect. Beginning later this month, the ice nations will discuss an international accord that would impose a moratorium on commercial fishing until scientists have had a chance to study the fish populations and underwater environment. **Eventually, these waters would be opened for carefully managed fishing.** The immediate goal is to forestall the rapacious fishing fleets of Japan and China, for which the Arctic is an all too tempting target. Chinese trawlers already fish for krill in Antarctica, about 7,000 miles from China. The Arctic is 5,000 miles away. In a curious way, **the year-round Arctic ice, which has persisted for some 100,000 years, has made international agreements covering the use of these waters by Arctic nations unnecessary.** If an Arctic fishing accord is reached — and we firmly believe that one is essential — it will be only the third such agreement; the first two regulated search-and-rescue operations and responses to oil spills as new drilling areas and shipping lanes opened up in coastal waters.



INTRODUCTION: With global warming arctic sea ice is decreasing at $-3.1 \times 10^3 \text{ km}^3 / \text{decade}$ (see chart B & C). The area of arctic ice is also decreasing (see chart A). Chart A shows the average area of arctic ice is $15 \times 10^6 \text{ km}^2$. The ice is melting due to arctic surface air temperatures increased $3-6 \text{ C}^\circ$ in past decade (see chart D). Consider the volume of air (V_{air}) above the $15 \times 10^6 \text{ km}^2$ area of ice and ~...say 30,000 ft. /5.68 mi./9.09 km. thickness (or height) as the source of the heat (Q) needed to MELT (solid ice to liquid water at 32° F) sea ice.

HINTS: $\rho_{\text{ice}} = 917 \text{ kg/m}^3 = m_{\text{ice}}/V_{\text{ice}}$, $\rho_{\text{air}} = 1.225 \text{ kg./m}^3 = m_{\text{air}}/V_{\text{air}}$, $(L_f)_{\text{ice}} = 330 \text{ KJ/kg.} = Q/m_{\text{ice}}$, $Q = c_{\text{air}} m_{\text{air}} \Delta t$, $c_{\text{air}} = 1 \text{ KJ/kg C}^\circ$, $m^3 = 10^{-9} \text{ km}^3$, $\text{km}^2 = 10^{-6} \text{ m}^2$, $Q_{\text{gained by ice to melt}} = Q_{\text{lost by arctic air above ice}}$

QUESTIONS: Our goal here is to find the average increase (Δt) in arctic air temperatures over the past decade. The higher air temperatures are responsible for $3.1 \times 10^3 \text{ km}^3$ of arctic ice to melt over past ten years. (a) Find mass (in kg.) of arctic ice (m_{ice}) melted over the past decade? (b) Find heat ($Q_{\text{required by ice to melt}}$) needed to melt $3.1 \times 10^3 \text{ km}^3$ ice over the past decade? (c) Find volume (in m^3) of air (V_{air}) 9.09 km. above arctic ice area of $15 \times 10^6 \text{ km}^2$? (d) Find mass of air (m_{air}) above average ice area of $15 \times 10^6 \text{ km}^2$? (e) Find Δt due to heat lost from arctic air to melt arctic ice over ten years? Note: If arctic air temperature did not rise heat would not be available from warmer air to flow to sea ice melting the sea ice. Hint for (e) below:
 $Q_{\text{gained by ice to melt}} = Q_{\text{lost from air}}$, $(L_f)_{\text{ice}} m_{\text{ice}} = c_{\text{air}} m_{\text{air}} \Delta t$ thu... $(L_f)_{\text{ice}} m_{\text{ice}}/c_{\text{air}} m_{\text{air}} = \Delta t$

ANSWERS: (a) $\sim 2.843 \times 10^{15} \text{ kg.}$, (b) $\sim 938 \times 10^{15} \text{ KJ}$, (c) $\sim 136 \times 10^{15} \text{ m}^3$, (d) $\sim 166.6 \times 10^{15} \text{ kg}$, (e) $\sim +5.6 \text{ C}^\circ$

VERIFICATION NOTE: National Oceanic and Atmospheric Administration (NOAA) reports autumn arctic air temps. up by 10.8 F° or $\sim 6 \text{ C}^\circ$. See chart D.