Quiz #1

The Greenland ice sheet contains ≈3 million Gt of grounded ice (ice resting on land); the Antarctic ice sheet contains ≈27 million Gt of grounded ice.

1. If climate change causes 10% of this ice to melt, by roughly how many feet would mean sea level rise? The oceans cover about 360 million square kilometers; ignore increases in this area due to flooding of land; 1 meter = 3.3 feet. (8 pts)
2. The area of the ocean will increase as sea level rises. Will actual sea-level rise be bigger or smaller than you calculated in part 1? (2 pts)

Quiz #1 Solution

3 + 27 = 30 million Gt of ice; 10% ($3 \cdot 10^6$ Gt melts):

$$\left[3 \cdot 10^6 \text{ Gt}\right]\left[\frac{10^9 \text{ t}}{\text{Gt}}\right]\left[\frac{\text{m}^3}{1\,\text{t}}\right]\left[\frac{1}{360 \cdot 10^6 \text{ km}^2}\right]\times$$

$$\left[\frac{\text{km}^2}{10^6 \text{ m}^2}\right]\left[\frac{3.3 \text{ ft}}{\text{m}}\right] = 27 \text{ ft}$$

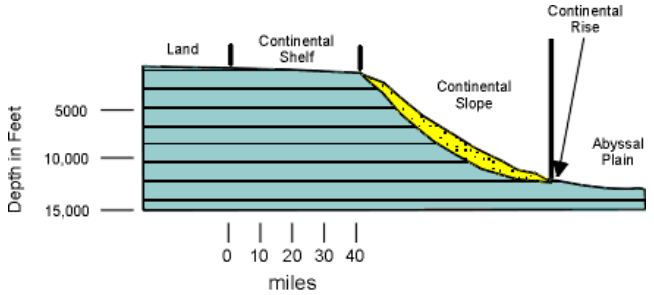
Note that ocean area is in the denominator; if this increases (due to flooding of land), sea-level rise will be smaller. How much smaller?

- We know mass and area
- We want length:

$$(\text{mass})\left(\frac{\text{volume}}{\text{mass}}\right)\left(\frac{1}{\text{area}}\right) = (\text{mass})\left(\frac{\text{length}^3}{\text{mass}}\right)\left(\frac{1}{\text{length}^2}\right)$$

$$= \text{length}$$

Quiz #1: Beyond the Solution

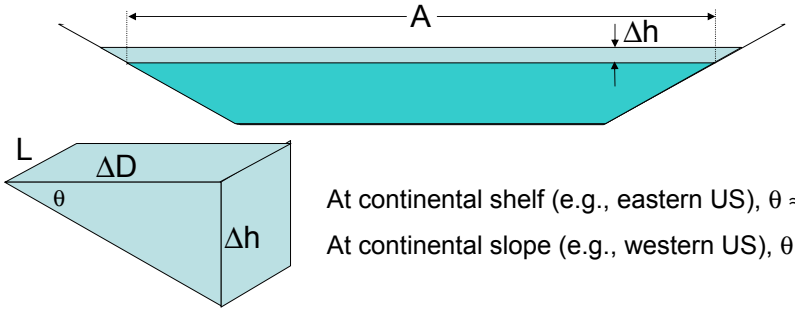


Continental Shelf and Slope off New York

Continental Shelf and Slope off San Francisco

Quiz #1: Beyond the Solution

- Very roughly, we can model the solid surface as a trapezoid:



At continental shelf (e.g., eastern US), $\theta \approx 1°$

At continental slope (e.g., western US), $\theta \approx 5°$

$$\Delta D = \frac{\Delta h}{\tan\theta} \cong \frac{57\,\Delta h}{\theta} = \frac{(57)(8.3\text{ m})}{\theta} \approx \frac{500}{\theta}$$

Quiz #1: Beyond the Solution

- How much land is flooded?

$$\Delta D \approx \frac{500}{\theta}$$

- About 500 m if $\theta = 1°$
- Flooded area $\approx \Delta DL$
- Length of coastline $\approx$ 600,000 km
- ΔDL = (0.5 km)(600,000 km) = 300,000 km^2 $\approx$ Poland; increase in ocean area: (0.3)/(360) = 0.0008 $\approx$ 0.1%

Quiz #1: Beyond the Solution

$$\Delta V = A\,\Delta h + \frac{\Delta h^2 L}{2\tan\theta} \qquad \frac{L}{2\tan\theta}\Delta h^2 + A\,\Delta h - \Delta V = 0$$

$$\Delta h = \frac{-A \pm \sqrt{A^2 + \frac{2\Delta V L}{\tan\theta}}}{\frac{L}{2\tan\theta}} = \frac{A\tan\theta}{L}\left[\sqrt{1 + \frac{2\Delta V L}{A^2\tan\theta}} - 1\right]$$

$$\cong \frac{A\tan\theta}{L}\left[\frac{\Delta V L}{A^2\tan\theta} - \frac{1}{8}\left(\frac{\Delta V L}{A^2\tan\theta}\right)^2\right] = \frac{\Delta V}{A}\left[1 - \frac{\Delta V L}{A^2\theta}\right]$$

$$= (8.3\text{ m})\left[1 - \frac{(8.3\text{ m})(6\cdot 10^8\text{ m})}{(3.6\cdot 10^{14}\text{ m}^2)\left(\frac{1}{57.3}\right)}\right] = (8.3\text{ m})(0.999)$$