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Abstract

This article assesses the impact on global sea levels if some of America's major coastal cities were to be submerged in giant underwater domes to protect them from flooding due to global warming. It was found that by submerging New York, Los Angeles, Boston, Washington DC, San Francisco, Seattle and Miami, global sea levels would only rise by $3.61 \times 10^{-3} \text{ m}$ (or 0.361 cm).

Introduction

Rising sea levels due to global warming causing ice caps and glaciers to melt is a serious threat to the global population. Many different approaches have been taken to protect major cities from these rising sea levels, from water pumps in the Netherlands, sea-wall barriers and even the complete abandonment of settlements. Many cities along the American coasts are at risk from these rising sea-levels. In this article we imagine that extreme measures are taken to protect these cities by encasing them in underwater domes and assess what impact that would have on the global sea levels and, as a result, other major coastal cities.

Discussion and Results

At its longest point New York city is *35 miles* (56.327 km) [1] long and its tallest building is the One World Trade Centre at 541 m [2]. Conveniently, when imagining a circle of diameter 56.327 km encasing New York, the One World Trade Centre (and therefore tallest point) is approximately central. As such, we will imagine that the city is encased in a dome of diameter, $d = 57 \text{ km}$, height, $h = 550 \text{ m}$, with a strong bar-

rier made of an in-compressible material and is submerged in the ocean. To keep the people living in the submerged city alive, air pipes would need to extend from the dome to the surface to provide oxygen and remove carbon dioxide, but the assumption shall be made that the additional volume of these tubes is negligible by comparison to the dome itself. The thickness of the dome is also considered to be negligible by comparison to the volume of the dome. This dome would have a shape more comparable to a paraboloid than a hemisphere due to the big difference in the base radius and the height. The equation for the volume of a paraboloid, V , from [3] is:

$$V = \frac{1}{2}\pi\frac{d^2}{2}h, \quad (1)$$

and so the dome would have a volume of $7.02 \times 10^{11} \text{ m}^3$.

What effect would this have on the rest of the world? The Archimedes Principle states that the amount of water that is displaced by a fully submerged object equals the volume of the submerged object. To then determine how much the sea levels would rise as a result, this would be spread over the surface area of the interconnected oceans, A_{oceans} . As such the sea level

rise, Δx , can be calculated using,

$$\Delta x = \frac{V}{A_{oceans}} \quad (2)$$

where A_{oceans} is $3619 \times 10^8 \text{ m}^2$ [4].

Additionally, imagining that the dome was submerged on the sea floor at a depth of 600 m (enough to cover the dome, including its thickness with some additional room left) the pressure, P , at the base of the dome can be calculated as seen in [5] by:

$$P = \frac{F}{A} = \rho g \Delta h \quad (3)$$

where ρ is the density of sea water, g is the acceleration due to gravity and Δh is the depth. For this example, the pressure felt at the base of the dome is $6.06 \times 10^6 \text{ Pa}$. It is thought that humans can only withstand pressures while diving of 3-4 atmospheres [6] (1 atmosphere being $101 \times 10^3 \text{ Pa}$), and the current world record for the deepest scuba dive is 332.35 m [7] so it would probably not be suitable for those living in the dome to exit and swim around near the base.

Using Eq. (2), if New York city were to be submerged in such a way, the global sea level would only rise $1.94 \times 10^{-3} \text{ m}$ (or 0.194 cm) which is too small to have any noticeable impact.

However, there are many other cities along the American coast that would also be under threat of flooding such as Los Angeles (1302 km^2), Boston (232 km^2), Washington DC (177 km^2), San Francisco (121 km^2), Seattle (217 km^2) and Miami (145 km^2) as examples (sizes taken from [9]). If each of these cities were also placed into an underwater dome in addition to New York, again taking the maximum height as 550 m by assuming that the cities are flat (so topography does not affect the maximum height), we evaluate,

$$\Delta x = \frac{V_{NY} + V_{LA} + V_B + V_{DC} + V_{SF} + V_S + V_M}{A_{oceans}} \quad (4)$$

where the volume of the domes of each city are calculated by approximating each state as circular and taking the radii of each dome to be $r = \sqrt{A/\pi}$. As such, the sea level increase

due to all of these underwater cities would be $3.61 \times 10^{-3} \text{ m}$.

Conclusion

Encasing New York and other major American coastal cities in underwater domes and placing them under the ocean would protect them from the effects of flooding due to rising sea levels with minimal effect of the global sea levels (and therefore minimal impact on other at-risk cities). However, the citizens within would not be able to explore the regions outside of the base of the dome due to the high pressure at that depth in the ocean.

References

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