Journal of Interdisciplinary Science Topics

Scuba Diving in Europa’s Ocean: Exploring Jupiter’s Moon

Caitlin Warren FRAS
Natural Sciences (Life and Physical Sciences), School of Biological Sciences, University of Leicester
14/03/2025

Abstract
Scuba diving in Europa’s subsurface ocean offers a unique opportunity for exploration and scientific research. Despite the challenges posed by low temperatures, a thick ice shell and radiation, diving technologies from polar environments and long-duration dives on Earth could provide a foundation for such exploration.

Keywords: *Sports; Physics; Planetary Science; Space Exploration; Scuba Diving; Europa*

Introduction

Europa was once thought to be geologically uninteresting, but since the Voyager 1 and 2 missions in the 1980s, the discovery of a subsurface ocean beneath its icy crust has sparked significant scientific interest [1]. This ocean, which may contain liquid water, could provide the necessary conditions for life [2]. With the recently launched Clipper probe set to arrive at Europa in 2030, new data will provide key insights into its subsurface ocean and its potential to support life, making it an intriguing target in the search for extraterrestrial life [3].

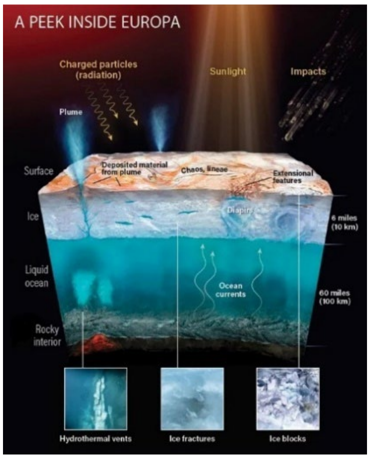

Figure 1 – Artist’s impression of Europa’s interior, displaying the various layers of ice, liquid water and its rocky interior [4].

On Earth, extreme ocean environments, such as those beneath Antarctica's ice, have been explored through scuba diving. By drawing on existing knowledge and experience from underwater exploration in Earth’s harshest environments, this paper explores the feasibility of diving in Europa’s ocean, which could offer valuable scientific insights into Europa’s environment and contribute to understanding extraterrestrial habitats.

Environmental conditions

The temperature of Europa’s subsurface ocean ranges from 0 to –4 °C [5], significantly warmer than its surface temperature of around –200 °C [6]. This temperature difference is due to tidal heating from gravitational interactions with Jupiter and neighbouring moons, as well as radiogenic heating and thermal exchange with Europa’s silicate mantle, which prevent the ocean from freezing solid [7]. With temperatures comparable to Earth’s polar seas, human exploration could be feasible with appropriate thermal protection.

There have been many estimates made about the thickness of the ice shell that surrounds the entire moon, ranging from 1 to 50 km [8]. This vast range means that the true thickness is essentially unknown, however, the range could vary by location due to differences in heat flow and it could also fluctuate over time [9]. While this variability adds uncertainty, drilling through the ice may be possible. For example, the deepest hole ever drilled in ice was 3.8 km during the Vostok drilling project in Antarctica (Figure 2) [10]. If the ice shell is thin enough, it could potentially be drilled to provide divers access to the ocean.

Other issues arise from Europa's harsh environment, particularly due to its high radiation levels. The surface is exposed to intense ionising radiation from Jupiter's magnetosphere [11], posing risks to humans. However, the ice shell provides natural shielding by blocking much of this radiation [12], meaning protection is mainly needed for surface activities, while exposure below the ice would be significantly reduced. Given the potential thickness of the ice, subsurface habitats could be a viable option for shelter when divers are out of the water.

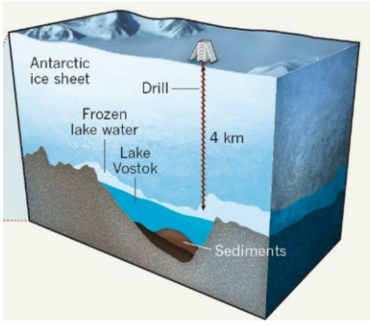

Figure 2 – Diagram showing the ~4 km hole that was drilled at Lake Vostok, Antarctica [13]. Similar techniques could be used on Europa for ocean access.

Pressure and Depth Considerations

Europa's subsurface ocean is estimated to be 100 km deep, making it one of the deepest oceans in the Solar System [14]. Whilst its lower gravity (1.314 ms^{-2}) results in a slower pressure increase with depth than on Earth [15], the immense depth means that pressures near the seafloor could exceed 1200 bar, similar to Earth's Mariana Trench which has a seafloor pressure of around 1100 bar [16].

For comparison, the deepest recorded scuba dive on Earth reached around 332.5 m [17]. At this depth on Earth, the pressure is around 33 times that of Earth's atmosphere, or 33 bar [18]. In order to calculate how deep a diver would have to go on Europa to be met with 33 bars of pressure, Equation 1 is used:

$$p = \rho g h + p_0, \quad (eq^n\ 1)$$

The hydrostatic pressure equation, where p is hydrostatic pressure in Pa, ρ is density in kgm^{-3}, g is acceleration due to gravity in ms^{-2}, h is the depth in m and p_0 is the atmospheric pressure at the surface in Pa. In this instance, p_0 is negligible due to Europa's extremely low atmospheric pressure of 0.1 µPa [19]. The density of water is assumed to be the same as that of Earth's seawater, which has a mean density of 1036 kgm^{-3} [20]. The acceleration due to gravity on Europa is 1.314 ms^{-2} [15]. Finally, the desired pressure of 33 bar in Pa is 3.3×10^6. Rearranging Equation 1 for h and inputting these values yields Equation 2:

$$h = \frac{3.3 \times 10^6}{1036 \times 1.314} = 2424\ m \text{ or } 2.4\ km. (eq^n\ 2)$$

Therefore, a human could theoretically dive down to 2.4 km on Europa and experience similar pressure as a 330 m dive on Earth. However, the prolonged dive time and harsh environment would require specialised equipment and advanced life-support systems.

Technical Considerations

Europa's extreme environment presents several technical challenges for scuba diving. Divers would need specialised dry suits, similar to those used in polar diving, to provide thermal protection against the moon's low temperatures. These suits are designed with insulating layers and heavy-duty, tear-resistant materials that withstand harsh conditions while maintaining warmth and flexibility [21]. Buoyancy control is another key challenge. The insulating undergarments in the dry suit increase the suit's volume, making it harder to maintain neutral buoyancy. This requires additional weights and careful management of air pockets to prevent sudden shifts in balance [21]. For prolonged dives in Europa's extreme depths, a gas blend such as trimix—helium, nitrogen and minimal oxygen—would be ideal. Trimix reduces the risk of nitrogen narcosis and oxygen toxicity, allowing for longer, safer dives [22]. Given that the longest open-water dive lasted 145 hours [23], such extended dives are possible, enabling prolonged exploration of Europa's depths.

Conclusion

Multiple challenges arise when considering scuba diving in Europa's subsurface ocean, with the primary difficulty being drilling through its thick ice shell. Additional obstacles include extreme temperatures and radiation. However, technologies from polar diving and long-duration expeditions on Earth provide a solid foundation for exploration. Specialised dry suits, buoyancy control techniques and the use of trimix gas for extended dives would be required. Whilst extensive research and preparation would be necessary, diving on Europa could offer valuable insights into its potential for life and extraterrestrial habitats.

References

[1] Lunine, J.I. (2017) *Ocean worlds exploration*, Acta Astronautica, 131, pp. 123–130. DOI: 10.1016/j.actaastro.2016.11.017

[2] Kanik, I. & Paul De Vera, J.-P. (2021) *Editorial: Astrobiology of Mars, Europa, Titan and Enceladus - Most Likely Places for Alien Life*, Frontiers in Astronomy and Space Sciences, 8, p. 643268. DOI: 10.3389/fspas.2021.643268

[3] Cangahuala, L.A., Campagnola, S., Bradley, B.K., Boone, D.R., Buffington, B.B., Ludwinski, J.M., Nandi, S. & Scott, C.J. (2025) *Europa Clipper Mission Design, Mission Plan, and Navigation*, Space Science Reviews, 221(1), p. 22. DOI: 10.1007/s11214-025-01140-2

[4] Johnson-Groh, M. (2024) *How we might find life on Europa*, Astronomy, 5 March. Available at: https://www.astronomy.com/science/how-we-might-find-life-on-europa/ [Accessed: 27 February 2024]

[5] Melosh, H.J., Ekholm, A.G., Showman, A.P. & Lorenz, R.D. (2002) *Is Europa's Subsurface Water Ocean Warm?*, Lunar and Planetary Science XXXIII. Available at: https://www.lpi.usra.edu/meetings/lpsc2002/pdf/1824.pdf [Accessed: 26 February 2025]

[6] Ashkenazy, Y. (2019) *The surface temperature of Europa*, Heliyon, 5(6), p. e01908. DOI: 10.1016/j.heliyon.2019.e01908

[7] Lemasquerier, D.G., Bierson, C.J. & Soderlund, K.M. (2023) *Europa's Ocean Translates Interior Tidal Heating Patterns to the Ice-Ocean Boundary*, AGU Advances, 4(6), p. e2023AV000994. DOI: 10.1029/2023AV000994

[8] Allu Peddinti, D. & McNamara, A.K. (2019) *Dynamical investigation of a thickening ice-shell: Implications for the icy moon Europa*, Icarus, 329, pp. 251–269. DOI: 10.1016/j.icarus.2019.03.037

[9] Wakita, S., Johnson, B.C., Silber, E.A. & Singer, K.N. (2024) *Multiring basin formation constrains Europa's ice shell thickness*, Science Advances, 10(12), p. eadj8455. DOI: 10.1126/sciadv.adj8455

[10] Talalay, P.G. (2023) *Deep drilling in Antarctic ice: Methods and perspectives*, Earth-Science Reviews, 243, p. 104471. DOI: 10.1016/j.earscirev.2023.104471

[11] Cressey, D. (2012) *"Too soon" to confirm success of Antarctic lake drilling*, Nature, p. nature.2012.9986. DOI: 10.1038/nature.2012.9986

[12] Paranicas, C., Cooper, J.F., Garrett, H.B., Johnson, R.E. & Sturner, S.J. (2009) *Europa's Radiation Environment and Its Effects on the Surface*, *Europa*, pp. 529. Available at: https://ui.adsabs.harvard.edu/abs/2009euro.book..529P [Accessed: 27 February 2025]

[13] Van Ellen, L. & Peck, D. (2018) *Use of in situ ice to build a sustainable radiation shielding habitat on Mars*, Proceedings of the 69th International Astronautical Congress, IAC, 2018, pp.1-5. Available at: https://www.researchgate.net/publication/342145558_Use_of_in_situ_ice_to_build_a_sustainable_radiation_shielding_habitat_on_Mars

[14] Chyba, C.F. & Phillips, C.B. (2002) *Europa as an Abode of Life*, Origins of Life and Evolution of the Biosphere, 32(1), pp. 47–67. DOI: 10.1023/A:1013958519734

[15] Fowler, K.R. & Dyer, S.A. (2018) *Proposed landing on europa: instruments, radiation shielding, planetary protection, and mission*, IEEE Aerospace and Electronic Systems Magazine, 33(8), pp. 6–23. DOI: 10.1109/MAES.2018.180009

[16] Marion, G.M., Fritsen, C.H., Eicken, H. & Payne, M.C. (2003) *The Search for Life on Europa: Limiting Environmental Factors, Potential Habitats, and Earth Analogues*, Astrobiology, 3(4), pp. 785–811. DOI: 10.1089/153110703322736105

[17] Janela, M. (2014) *Ahmed Gabr breaks record for deepest SCUBA dive at more than 1,000 feet*, Guinness World Records. Available at: https://www.guinnessworldrecords.com/news/2014/9/ahmed-gabr-breaks-record-for-deepest-scuba-dive-at-more-than-1000-feet-60537.html [Accessed: 27 February 2025]

[18] NOAA (nd) *Water Pressures at Ocean Depths,* NOAA Pacific Marine Environmental Laboratory. Available at: https://www.pmel.noaa.gov/eoi/nemo1998/education/pressure.html [Accessed: 28 February 2025]

[19] Pappalardo, R.T., McKinnon, W.B. & Khurana, K.K. (2009) *Atmosphere of Europa*. Tucson: University of Arizona press (The University of Arizona space science series).

[20] Pawlowicz, R. (2013) *Key Physical Variables in the Ocean: Temperature, Salinity, and Density*, Nature Education Knowledge 4(4):13. Available at: https://www.nature.com/scitable/knowledge/library/key-physical-variables-in-the-ocean-temperature-102805293/ [Accessed: 28 February 2025]

[21] Marsh, A.G., Moran, A.L. & McClintock, J.B. (2013) *Scientific Polar Ice Diving*, In: Research and Discoveries: The revolution of science through scuba, pp.83-86. ISSN: 0196-0768

[22] Marinovic, J., Ljubkovic, M., Obad, A., Bakovic, D., Breskovic, T. & Dujic, Z. (2009) *Effects of Successive Air and Trimix Dives on Human Cardiovascular Function*, Medicine & Science in Sports & Exercise, 41(12), pp. 2207–2212. DOI: 10.1249/MSS.0b013e3181aa04cc

[23] Guinness World Records (2021) *Longest open saltwater SCUBA dive (male)*. Available at: https://www.guinnessworldrecords.com/world-records/longest-open-saltwater-scuba-dive.html [Accessed: 28 February 2025]