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A potential nanoscience and technology solution for ocean-based carbon dioxide removal and sequestration on a global scale: A remarkable opportunity for advanced analytical techniques

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On January 12, 2024, the title on the homepage of the National Oceanographic and Atmospheric Administration (NOAA) in the United States was “2023 was the world’s warmest year on record, by far.” Dr. Sarah Kapnick, NOAA Chief Scientist, said “I have to pause, and say that the findings are astounding.” Since 1850, the 10 warmest years have all occurred in the last decade, and Earth is already at 1.35° C warmer relative to pre-industrial levels. Globally, it is now realized that our dangerously warming planet is far from having these trends reversed without massive and affordable CO_2 removal from the atmosphere in the relatively near future. This is despite important and often successful attempts to begin to reign in CO_2 emissions, to expand solar and wind energy even ahead of expectations, and to greatly improve machine and grid efficiencies. On the other hand, the oceans already absorb likely between a quarter and a third of the CO_2 that humans put into the atmosphere each year. The CO_2 ends up dissolved in sea water, some taken up by phytoplankton, which is partly stored as biomass in the deep ocean for decades to millennia.

Ocean experiments in the past have already shown that small amounts of iron distributed in parts of the oceans that lack sufficient nutrients, and therefore have low phytoplankton populations, can be stimulated, resulting in more photosynthesis, and therefore more CO_2 uptake. However, these original in situ experiments were rudimentary and many more are needed to refine the process, with the intent to duplicate nature as closely as possible and to keep the oceans in a healthy, balanced state. We describe in this talk ways that, in principle, synthetic nanoparticles can be designed to simulate efficient phytoplankton population growth, and to possibly enhance phytoplankton aggregation and sinking so that a significant amount of biomass can reach ocean depths that will result in durable carbon storage. Modern nanotechnology could show the way to making ocean fertilization a reasonable and affordable way to sequester a substantial amount of atmospheric CO_2 per year, significantly and affordably slowing global warming.