COOLING THE WORLD WITH BUBBLES

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# INTRODUCTION

Several methods have been put forward that have been designed to cool our overheating planet. This one is based on that of Russell Seitz of Harvard and The Climate Institute in his paper “Bright Water” see https://dash.harvard.edu/bitstream/handle/1/4737323/Seitz\_BrightWater.pdf?sequence=1. However, it adds some new elements comprising: the use of long-lived nanobubbles, see http://www1.lsbu.ac.uk/water/nanobubble.html, rather than that of relatively short-lived microbubbles (minutes in pure water to hours or even days in seawater); their energy-efficient creation by means of Desai-Zimmerman Fluidic Oscillators (DZFO); and the means of delivery by way of Fiztops, which are low-cost, lightweight, solar-powered, conical or top-shaped units that are tethered or free-floating devices that disperse fizzy nanobubbles underneath them to the surfactant-rich, ocean ‘skin’ that gives nanobubbles an average life measured in months or even years, and which thereby could brighten the ocean surface effectively, albeit probably imperceptibly to the naked eye, and replicates the albedo effect of similar bubbles, though typically larger, shorter-lived and less-effective ones, found in ocean spume, whitecaps and water bodies.

# THE OCEAN SURFACE

In productive ocean waters, the surface waters can be regarded as a thin, organic, colloidal soup resulting from the release of buoyant organic chemicals from living and dead marine organisms. In oligotrophic, or impoverished waters, typical of the remote areas far from continental land, this soup is much thinner, and thus would not have such a life-prolonging effect on nanobubbles, unless its mineral nutrients, and hence net primary productivity, can be supplemented by such means as ocean fertilisation using buoyant flakes.

# OCEAN BUBBLES

Large ocean bubbles that are typically formed by wave action rise to the surface and burst, typically within minutes. Microbubbles tend to be unstable because of their high internal pressure. Eventually, they either burst on the surface or disappear as their contained gas leaks out into the gas-unsaturated surrounding water. Nanobubbles are different. For one thing, they are so small that they do not float to the surface because their buoyancy is too little to offset the viscous effect of water. Secondly, surfactants, particulates, colloids and charged ions in the surface water are attracted to nanobubbles air-water surfaces where they form concentric, shielding layers, and sometimes polygonal domains, that reduce the high surface tension of the nanobubbles. Thirdly, the shielding layers allow for the formation of gas-saturated zones that prevent further gas loss from the nanobubbles. Fourthly, it is surmised that the buoyancy of the attached surfactant layers would tend to cause the nanoconglomerates to rise to the surface where the nanobubbles would be protected from bursting by the shielding and would tend to form a thin, or even a mono, layer, and would be in the best location to provide maximum albedo. Moreover, whilst Seitz’ estimated that floating microbubbles would reduce evaporation, it could well be that the somewhat lateral reflection, refraction and absorption of sunlight by and into the micron-level thickness of ocean ‘skin’ would actually cause it to warm so much that evaporation actually increased, thereby cooling the water underneath substantially, as well as shading it, and indirectly causing more marine cloud brightening.

# NANOBUBBLE DISSEMINATION AND DISPERSAL

The top few microns of ocean are particularly rich in organics, thereby forming the perfect place for the dissemination of nanobubbles which are protectively coated in shells of surfactant and charged ions. Possibly with the addition of three buoyancy spars designed to lift its base to sea level, the flat underneath of each fiztop, formed by the diffuser laminate, is ideally placed to inject nanobubbles into the ocean surface layer where they would rapidly be surrounded by shielding. As even the gentlest wind, if not the bulge of the now less-dense, aerated water under it (or current for tethered fiztops), would cause the fiztop to move away from the recently-emitted bubbles, lateral nanobubble dispersion would be achieved. Whilst an even dispersion of nanobubbles within a locality over months would probably be best, their net effect on increasing albedo should not be much affected by somewhat uneven dispersion. Aerial or satellite photography should be able to detect the streams or concentrations of nanobubbled water that had been issued either from single fiztops or groups of them, even if such effects were invisible at close to sea level.

# ALBEDO EFFECTS

Whilst Seitz states that increasing the albedo of water in this way can reduce solar energy absorption by as much as 100W/m2, much lower levels are contemplated here, if only because such high levels might tend to have net deleterious effects on marine life. Low levels, perhaps 2-20W/m2, in the non-sunlight-limited regions of the tropical to temperate seas should have minimal adverse effect, and, for coral reefs, seagrass meadows and halothermally-stratified waters, should have strongly net beneficial effects.

Myhre et al., (2017) have shown that increasing the oceanic albedo by as little as 3.7W/m2 would offset the warming effect of doubling pre-industrial atmospheric CO2 concentrations. As the average solar strength at ground level is about 1,120W/m2 this does not seem to be an unachievable target. In fact, considerably more should be possible using fiztops extensively, without adversely affecting marine primary productivity. The ‘considerably more’ amount might well become essential, should we already have passed, or pass, environmental tipping points.

# EVAPORATIVE EFFECTS

The evaporative effects of introducing long-lived nanobubbles into the air-sea boundary layer have yet to be discovered. However, should much of the solar energy that otherwise would have penetrated metres into the ocean and there be largely transformed into heat be either reflected back from the ocean by the nanobubbles, or else somewhat laterally be multiply refracted, reflected and absorbed by materials in the boundary layer, then it should heat up considerably. This heating would then be largely, but not wholly, offset by evaporative cooling upwards and conduction and mixing downwards. However, given thermal stratification effects, the latter two are likely not to be as effective as is evaporative cooling. It is surmised that the evaporative cooling effect could be as much as several times more effective at moving heat energy vertically as that of the other two combined. Should modelling and experiments confirm this supposition, then a large percentage of the solar heat that is currently warming the ocean in the euphotic zone would no longer do so. Instead, it would be turned into water vapour, marine cloud, convected and reflected energy – thereby having a substantial and a net beneficial effect on radiative forcing, as well as tending to mitigate extreme weather events and ice loss.

# ECOLOGICAL EFFECTS

It is surmised that the local effects of such nanobubble dissemination would be: a modest cooling of the upper water column; a reduction in coral, seagrass, mangrove and kelp loss; and possibly mixed effects upon buoyant species such as *Sargassum* and *Trichodesmium*. It is also conceivable that, particularly in placid waters, the microlayer of heated surface water might reduce air-sea gas exchanges, at least during daylight hours, whilst it improved the gas-carrying capacity of the waters below the microlayer.

# FIZTOP CAPABILITIES

It is conjectured that a single fiztop unit, tethered in subtropical waters, would be capable of brightening some 3km2 of down-current ocean surface in a year, and that this would have the effect of cooling the surface waters by as much as 2.50C over a five year period, allowing for the effects of both shading and the additional, evaporative cooling. Cooling to some lesser extent would be provided to waters further down-current. With semi-annual cleaning by drone, the effective average operational life of a fiztop could be several years. Occasional refurbishment, initiated by automated status reports from the fiztop, might usefully extend this.

Early deployments of fiztops might be tethered ones, designed to protect coral reefs, mariculture facilities and seagrass meadows whilst optimising the design. Later, and more ambitious deployments, might be free-floating but recoverable units sited in ocean gyres, at intervals along the world-girdling warm surface waters of the Great Ocean Conveyor Belt, or to cover the remote and well-lit global ocean waters at densities, locations and seasons selected for their optimal regional effects on shading, cooling, stratification, fisheries management, extreme weather event mitigation, ice formation and downwind precipitation.

To increase fiztops’ capability and usefulness, (micro)sensors might be attached to them to sense and transmit near real-time data regarding: identity, location, status, insolation, humidity, atmospheric and sea surface temperature, precipitation, gas concentrations, cloudiness, wind and wave conditions (including that of passing tsunamis), salinity, acidity, turbidity, oxygenation, water composition, and noise above and below water. When fiztop density and coverage reached respectable proportions in a region, the sensor system could even operate to aid search and rescue operations there, or to act as a distress beacon, phone or life-jacket.

# FIZTOP COOLING EFFECTIVENESS

Seitz found, from a model that simulates how light, water and air interact, that microbubbles could double the reflectivity of water at a concentration of only one part per million by volume. Plugged into a climate model, he claimed that his microbubble strategy could cool the planet by up to 30C. Fiztop’s DZFO nanobubbles should be able to do much better and at a cheaper cost.

# FIZTOP R&D

**Phase 1.** Would calculate the cooling effect of 400nm diameter nanobubbles released into the ocean surface in subtropical waters at different concentrations. Modelling studies would then optimise their global potential and effects when ocean brightening by them is maintained in selected areas.

**Phase 2.** Prototype, evolve and establish the manufacture of the PET/titanium foil diffuser concept, the DZFOs, the other fiztop elements, their integration and uses.

**Phase 3.** Run a pilot in one of the coral areas now under threat of bleaching, possibly the Great Barrier Reef (GBR), with the help of Australian marine research agencies.

**Phase 4.** Scale this up to include larger areas, mariculture locations, free-floating arrays of fiztops, and their synergy with buoyant flake ocean fertilisation (BFOF) in oligotrophic waters.

# MARGINAL COSTING

# COSTING OPERATIONS

# COST EFFECTIVENESS

# GOVERNANCE

# INTERACTION WITH OTHER METHODS OF CLIMATE & OCEAN RESTORATION

# CONCLUSIONS