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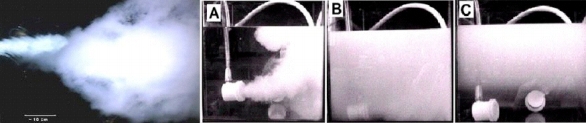
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**Bright Water: Hydrosols, Water Conservation and Climate Change**

*(Article begins on next page)*



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**Bright Water :**

**Hydrosols, Water Conservation and Climate Change**

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1. **bstract**
2. ecause air-water and water-air interfaces are equally refractive, cloud droplets and microbubbles dispersed in bodies of water reflect sunlight in much the same way. The lifetime of sunlight-reflecting microbubbles, and hence the scale on which they may be applied, depends on Stokes Law and the influence of ambient or added surfactants. Small bubbles backscatter light more efficiently than large ones, opening the possibility of using highly dilute micron-radius hydrosols to substantially brighten surface waters. Such microbubbles can noticeably increase water surface reflectivity, even at volume fractions of parts per million and such loadings can be created at an energy cost as low as J m to initiate and milliwatts m to sustain. Increasing water albedo in this way can reduce solar energy absorption by as much as 100 W m , potentially reducing equilibrium temperatures of standing water bodies by several Kelvins. While aerosols injected into the stratosphere tend to alter climate globally, hydrosols can be used to modulate surface albedo, locally and reversibly, without risk of degrading the ozone layer or altering the color of the sky. The low energy cost of microbubbles suggests a new approach to solar radiation management in water conservation and geoengineering: Don’t dim the Sun; Brighten the water.

**Figure 1: Photographs showing injection of ~100 cm /sec of ~ 1 volume % , ~ 1 micron bubble radius hydrosol into a pool of water (the scale indicates 10 cm). Left photo shows top view during injection. Photographs A and B show side views 10 seconds after initiation and at 60 seconds when injection is stopped. Photograph C shows distribution 120 seconds after end of injection.**

**Introduction**

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1. lthough the Earth has been described as “a pale blue dot,” its albedo is low because the deep water covering two-thirds of its surface is as dark as a blacktop parking lot, absorbing ~93% of incident solar radiation. The energy thus absorbed by the ocean tempers winter temperatures and drives the global hydrologic cycle. As the earth’s hydrosphere also stores most of the energy trapped by increasing concentrations of greenhouse gases, reducing its heat uptake by increasing surface albedo is a potentially important way in which human-induced warming from greenhouse gas emissions and landscape darkening-- might be counter-balanced.
2. oosting albedo to mitigate microclimates may antedate the edict of Solon that turned Athens into the original “shining city on a hill.” The ancient use of whitewash gave way to modern studies of white roof effects half a century ago (Neiberger 1957), but the potential of white water for climate mitigation has been largely overlooked. While air may seem an improbable watercolor pigment its effects are in plain sight -- it provides enough refractive index contrast to brighten ship wakes, waterfalls, and breaking waves. Besides being >10 less dense than solid pigments, air is free, and some paint manufacturers already economize on $1000 a tonne titanium dioxide by adding microbubbles to cheap white paint.

Bubbles require relatively little energy to create (Seitz 1958), and can increase the reflected (outgoing) solar flux *F* from a given body of water by providing voids that backscatter light. As spherical voids in the water column present the same refractive index contrast as round aerosol water droplets suspended in air, hydrosols are essentially atmospheric clouds turned inside out, and the formalism used to express the degree of planetary brightening Δ*F* , from clouds in the sky can be applied as well to hydrosol clouds in the sea, or any other body of water

Δ*F =* Δ*R*

*c*

*F*

*o*

µ

*o*

*(1-A*

*u d*

*c c*

*c*

(1)

where Δ*R c* is the change in the albedo of the upper water column (i.e., of the water surface) that bubbles produce, *Fo* is the solar irradiance, µ*o* is the cosine of the solar zenith angle, *A c* is the cloud cover fraction, and *T c* and *T c* are the up- and down-welling transmissivities of the air-water column under clear sky conditions. When subsurface bubbles approach aerosol droplets in number density and backscattering efficiency, they can render a water surface almost as bright as clouds in the sky. Though colorless, reflective bubbles increase the surface radiance and change the color of the ocean in ways reflecting the spectral backscattering and absorption of the undisturbed background waters (see figure 4 and Zhang et al. 2004). Unlike plankton blooms that can increase near surface energy absorption and water temperature , augmentation of ‘undershine’ by microbubbles can reduce net energy absorption. and lead to cooler daytime waters.

This paper considers issues relating to the creation and persistence of microbubbles and the potential for using reflective microbubble dispersions, , to manage solar radiation uptake by locally brightening some of the > 300 million square kilometers of fresh and salt water that cover most of the Earth. Such a dispersion is termed a‘ *hydrosol’ when, as*