Restoring the natural subtropical sulfur cycle without depleting stratospheric ozone

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The Earth system behaves as a self-regulating system comprised of physical, chemical, biological and human components.[1] In particular, marine phytoplankton have been found to affect marine stratocumulous cloud formation through biochemical means.[2] Ice cores reveal methanesulfonate (MSA) levels 5 times higher during glacial maxima than at present. Since MSA comes from oxidation of di-methyl sulfide (DMS), increased MSA indicates significantly higher DMS during ice ages compared to the present day.[3] DMS, isoprene and methyl iodide are known to generate atmospheric nuclei leading to low-altitude stratocumulus clouds, which reflect solar radiation back into space, cooling the Earth.

Primary productivity has decreased in stably stratified oceans with positive temperature anomalies.[4] In the North and South Pacific, North and South Atlantic, outside the equatorial zone, the areas of low surface chlorophyll waters have expanded at average annual rates up to 4.3%/yr and replaced about 6.6 million km^2 of higher surface chlorophyll habitat with low surface chlorophyll water over the past decade.[5] The rates of expansion observed already greatly exceed recent model predictions. As the entire stably-stratified ocean warms further in the years ahead, primary productivity in low and mid latitudes will continue to decrease.

Restoring plankton biomass in the subtropical and tropical ocean deserts is expected to bring the Earth system into equilibrium at a lower global temperature.[6] This approach can be undertaken economically using arrays of renewable-energy ocean pumps, free-drifting in the mid-ocean gyres, which restore nutrient levels in aquatic desert (low-nutrient, low-chlorophyll) regions by restoring upwelling of deeper water. This approach closely follows natural upwelling that occurs during cooler climate, without increasing atmospheric CO_2, since at least as much inorganic carbon is fixed as is upwelled. A manufacturing program of 300,000 pumps per year could double DMS levels within two decades based on known pumping efficiencies of existing pumps.[7] This program would significantly increase low-latitude cloud reflectance, enough to reduce global temperature in spite of elevated anthropogenic CO_2 levels, buying time to reduce CO_2 in the atmosphere. Ocean pumps based on renewable energy can be manufactured in high volume for less than $2000 per pump.

Possible side benefits accrue in the form of assisting ocean fisheries and possible oceanic carbon uptake, but the main benefit of restored phytoplankton biomass will contribute significantly to lower global temperature and help to re-establish global thermal equilibrium. Even though the Earth system has thrived in the past with phytoplankton levels much higher than at present, in the worst case, any increase in the size of low-oxygen regions can be addressed by down-welling high-oxygen water to appropriate depths.

Significantly, restoring DMS levels will increase global reflectivity without depleting the ozone layer, unlike stratospheric sulfate approaches. DMS has a short lifetime of a few days, insufficient to reach the stratosphere before being recycled in the lower troposphere. Nonetheless, that timescale is sufficient to significantly increase low-altitude stratocumulous cloud formation in the tropics and mid-latitudes, where the most sunlight falls.

Photosynthetic biomass correlates strongly with improved Earth system climate regulation: the more plant biomass, the more carbon is removed from the atmosphere on short and medium timescales. This biomass increase can be either accomplished by returning most arable farmland to forest, or by restoring phytoplankton levels in the ocean. Given this choice and the need to feed the human population, restoring phytoplankton biomass may be the best option to help the Earth system avoid an imminent, unregulated excursion to a hotter, drier Earth similar to the Eocene period, with much less ability to generate food and support a planet in the coming decades with 10 billion human inhabitants.

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[1] The Amsterdam Declaration on Global Change, Challenges of a Changing Earth: Global Change Open Science Conference Amsterdam, The Netherlands 13 July 2001.

[2] Bates, Timothy & Patricia Quinn, Derek Coffman, Drew Hamilton, James Johnson, & Theresa Miller, "Oceanic Dimethylsulfide (DMS) and Climate," NOAA, http://saga.pmel.noaa.gov/review/dms_climate.html.

[3] Saigne C. & M. Legrand, "Measurements of methanesulphonic acid in Antarctic ice," Nature 330, 240 - 242 (19 November 1987); doi:10.1038/330240a0

[4]Behrenfeld *et al.*, 2006

[5] Polovina, J. J., E. A. Howell, and M. Abecassis (2008), Ocean's least productive waters are expanding, Geophys. Res. Lett., 35, L03618, doi:10.1029/2007GL031745.

[6] Lovelock, The Revenge of Gaia, Basic Books, 2006

[7] www.atmocean.com.