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Limiting Global Temperature Rise with Floating Mirrors on Equatorial Waters

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Abstract

The long-term solution to global climate warming is the necessary transition from a primarily fossil fuel economy to renewable energy sources. Recent IPCC (Intergovernmental Panel on Climate Change) Special Report emphasizes the need to limit global temperature increase relative to pre-industrial level to 1.5°C. A previous target had been a limit of 2°C rise via the IPCC RCP (Representative Concentration Pathway) 2.6. The more stringent target of 1.5°C requires reduction of Green House Gas(GHG) emissions to near zero around mid-century. Failure to limit temperature rise may result in positive feedback such as ice shelf melting a factor affecting global albedo that could further accelerate warming. There are tools available to climate management that can be implemented to mitigate such potential runaway scenario. We propose here a solar radiation reduction approach that can be easily deployed and recalled. The basic concept is the deployment of floating mirrors near the equatorial international waters. We describe the design of such mirrors and features that would confine the mirror positions within a narrow band of the equatorial region. An example for an ~1°C reduction is described.

Keywords: Solar Radiation, Global Temperature, Floating mirrors

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1. Introduction and Background

The warming of the earth due to humanity's thirst for energy derived from fossil fuel has improved the lives of millions, but has rapidly increased GHG over the past decades leading to global temperature increase. GHG trapping of IR (infrared) radiation has led to an international effort to study multiple scenarios that could lead to elevated global temperature relative to pre-industrial temperature. The temperature increase estimates range from 1.5°K in the best case to ~3°K in a worse case by 2100 (Edenhofer 2014). Current temperature rise is already 0.87°C (Masson-Delmotte 2019) compared to that of the pre-industrial reference. The recent IPCC Special Report SR15 (Allen 2018) stresses the need to limit global temperature increase over pre-industrial level to no more than 1.5°C. This is equivalent to the stringent RCP 1.9 case described by Rogelj(2018) reaching near zero emission by mid-21 century. At our current rate of temperature rise of 0.18°C per decade (Lindsey 2020), 1.5°C rise will be crossed around mid-century and continue to rise. The next target path way is RCP 2.6 requiring that CO2 emission start to decrease in 2020 reaching near zero by or before 2100 to stay below a rise of 2.0°C (Kainuma 2018). CO_2 emission has, in addition to contributing to global temperature increase, many other long-term impacts such as ocean acidification (NRC 2010) and adverse effects leading to ecosystem vulnerability (Jacob 2018), just to name a few. However, the global temperature increase has severe effect on polar ice shelves (Adusumilli 2020, Lai 2020). Ice loss is one factor among others that contributes to sea level rise. For RCP 2.6, a sea level rise of up to 0.5 M is anticipated (Stocker 2013). Sea level rise can approach 1 M (Schaeffer 2012) in a worse-case scenario affecting severely all coastal habitats. Such a rise can erase coastal properties valued in magnitudes hard to quantify.

More severely, polar ice shelf loss can have potentially a positive feedback effect further accelerating global warming. Using Antarctica as an example, its albedo (0.6-0.7) is dominated by the Ice shelf with values of 0.8-0.9 (Brandt 2005). If ice shelf instability and losses lead to an Antarctica albedo reduction of 0.1, it could lead to an equivalence of ~ 3 W/M^2 of additional solar radiation penetrating and absorbed by the earth (see Footnote 1). This added solar input translates into an additional radiative forcing of ~0.75 W/M^2. Such an amount will start to interfere with the efforts required to achieve the desirable RCP 1.9. This level of added radiative forcing could potentially derail the RCP 1.9 efforts and turn the associated carbon dioxide reduction (CRD) program for RCP 1.9 into RCP 2.6. The

Antarctica example is used merely to illustrate how small changes in albedo in a local geographic area may have profound impact on radiative balance. While there is a global effort not necessarily coordinated among nations in targeting CO_2 mitigation and sequestration, it would be prudent to initiate a parallel effort in reducing the global temperature despite the concerns for solar radiation management termination shock (Parker 2018).

There has been a number of proposals for managing solar radiation, or Solar Radiation Management (SRM). Two space-based approaches have been proposed; the deployment of space deflectors at the Lagrange 1 gravitational saddle point between the sun and the earth (Early 1989), or a ring of near-earth space mirrors (Wood 2012). The former approach requires, in addition, positional feedback for stability. More prohibitive is the cost of deployment which would exceed by orders of magnitude of the global GDP. Painting roof tops white has also been suggested (Akabari 2009). A simple estimate based on global rooftop area leads to nearly the need of 2 orders of magnitude of homes that are currently in existence. Deploying mirrors on land will require the equivalent of twice the area of Saudi Arabia all deployed near the equator, an impractical approach with likely few cooperating nations. Microbubble creation in the ocean by ships to increase ocean albedo has been proposed (Seitz 2011). This requires constant replenishment. Operating ships to generate hydrosols may become energy and environmentally costly defeating its original intent. Marine cloud brightening is a low altitude cloud seeding with sea salt near ocean surfaces (Latham 1990). Atmospheric particle seeding to change the earth's albedo has also been suggested (Crutzen 2006) and is currently the most researched approach. This requires a continuous effort in high altitude discharge to keep up with sedimentation. An ongoing scientific effort, Stratospheric Controlled Perturbation Experiment, to study aerosol physics and atmospheric chemistry that could lead to solar geoengineering is in progress (Dykema 2014). The long-term goal is to understand climate impact of aerosol deployment in the stratosphere possibly leading to its safe use for modulating solar irradiance on a global scale. Atmospheric seeding, whether high or low altitude again requires constant replenishment which is a constant source of energy input and a continuing source of particulate discharge with yet unknown environmental impact. Aerosol, cloud seeding, and space mirrors continue to command interest in various SRM and RCP modeling scenarios (Niemeier 2013)

In this paper, we propose an armada of mirrors floating on the ocean near the equator to permit global temperature tuning. Using this Floating Mirror (FM) approach as an independent knob to mitigate temperature increase, a straight forward reflection of a small portion of the solar radiation that reaches the earth's surface back into space can reduce global temperature that is continuing to rise even with current GHG mitigation and CDR (carbon dioxide reduction) approaches. Most importantly, it can potentially stave off positive feedbacks that can negate climate mitigation efforts. This approach does not encroach on any national or private property rights. The quantity of floating mirrors can be easily increased or decreased as needed. This paper offers an alternative engineering approach to solar radiation reduction to slow global temperature rise. There is no attempt to address concerns for SRM termination shock, which is the primary objection to the implementation of any or a combination of the existing SRM proposed approaches. The complexity of SRM implementation on a global scale applies to all SRMs.

2. Floating Mirror Concept

A potentially effective way to increase the albedo of the earth thus countering the global temperature increase caused by the increase in atmospheric GHG load is the deployment of FMs on the ocean surfaces near the equator for maximum mirror area utilization. The earth's temperature is governed by the balance between global solar input and the radiative infrared emission into space. The earth's radioactive internal heat source (Davis 2010) is miniscule compared to the solar input, $\sim 2\times10^{-4}$ smaller than the total solar irradiance. The global temperature has settled around the average of $\sim 300^{o}$K.

To put the concept in perspective, reducing the global temperature by 1^{o}K would require the reduction of 1/300 of the solar radiation that is absorbed by the earth's atmosphere and surfaces. Since the proposed method relies on mirror reflection deployed on the ocean surface, it is effective only if the solar radiation reaches the mirrors and that the reflected radiation escapes into space. Neither pathway is 100% transparent. Of the amount of solar radiation that is absorbed (one minus the albedo of the earth ~ 0.3), which is 70%, 1/3 of which cannot be reflected due to absorption by the clouds (Webb). This contributes to 1.5 times higher reflective surfaces than required without cloud absorption. Furthermore, the outgoing reflected rays (Webb) will be attenuated by 40% due to cloud absorption (23%) and back scattering (17%) leading to an effective transmission of 60%. This outward going inefficiency will require an additional surface area of a factor of 1.7. Therefore, to effect a 1^{o}C global temperature reduction using surface mirrors, the required surface area will be 2.5 times that if the surfaces were to be deployed in outerspace. Thus, to achieve a 1^{o}K reduction will require ~2.5/300 solar radiance reduction (~0.8%) on ocean surfaces. Using simple geometric consideration, this translates to a band of mirrors deployed around and on the open equatorial waters, slightly over one half of the earth's circumference (earth's diameter = 12,700 Km),with ~ 140 Km width. With natural dispersion and the FM containment features to be discussed below, the collection of FMs would likely be dispersed, not clustered but confined to a few hundred kilometers near the equatorial waters.

Floating Mirrors (FM) should have the following features for practical implementation.

1) Reflective on both sides such that waves that may flip the mirrors would not affect the reflective function.
2) Effective density of near one.
3) Hermetically sealed.
4) Sized to be non-interfering on ship navigation and marine life, i.e., 1 to 3 meters in dimension.
5) Self-homing towards the equator to take advantage of (a) near normal illumination and reflection, (b) the relative calm in a small latitude band along the equator, (c) the use of equatorial currents and countercurrents to minimize FM drifts toward land masses.

The basic construction is simple with 2 convex discs made from PVC (polyvinyl chloride) or other polymer substrates sealed along its base rims. The surfaces are coated with reflective elemental metal, such as Al. The mirror layer is protected with a coating of polyvinylidene chloride commonly used in semiconductor circuits against moisture penetration. Other protective coatings can also be used. The amount of the PVC used is determined by its thickness and governed by the need for buoyancy. For any diameter, the minimum convexity will be limited by the amount of air space needed in the disc. The volume of air to that of the PVC must be greater than (ρ- 1), where ρ (~1.38 gm/cc) is the density of PVC, and taking the density of sea water to be one. This criterion can be easily satisfied even with additional components needed for a smart FM to satisfy feature (5) stated above and further discussed below. Hermeticity can be achieved through standard heat welding for thermal plastics such as PVC. The practical size range would fall between 1 to 3 meters in diameter. For a 1-meter diameter reflector, ~3 x 10^{12} reflector units will need to be deployed, while 10 times less would be needed for 3-meter diameter reflectors. Discs of this size range will have little impact on shipping lanes since ships would advance and push aside discs without damage to itself nor to the discs.

Without feature (5), discs deployed near the equator but were swept away from the optimum location through ocean currents will disperse from the equator and start losing its effective reflectivity due to projection area decrease. Wandering disc will need to be picked up and relocated back to the equator, a rather impractical scenario. Three or four islets will be provided around the rim for easy pickup from the water. However, nature is on our side. There are westerly flowing North Equatorial and South Equatorial surface currents which are partially balanced by the easterly flowing Equatorial countercurrent (Bischof and Mariano 2004). The North and South currents are mainly within ±20^{o} latitude(Bonhoure 2004, Bischof and Rowe 2004) with the easterly equatorial counter current sandwiched between the two westerly currents. Thus, deployed Floating Mirrors would mainly be confined by such "recirculation" within latitudes that are favorable for Solar reflection provided the FMs can auto-contain themselves within a narrow band near the equator.

3. Smart Floating Mirrors

A smart FM will need to have (1) north-south alignment, (2) ability to know its latitude and longitude location near the equator, and (3) an active drive to propel it towards a long-term equilibrium location both latitudinally and longitudinally. The deployment latitude would be within the equatorial quiet zone of between ±5^{o}. However, if the discs veered from the equator to a latitude of 15^{o}, outside of the desirable zone, the projected area is decreased only by ~4%. Another important reason for keeping the FMs near the equator is to avoid these mirrors from being trapped in hurricanes. The Coriolis effect, a necessary component for hurricane initiation and formation,is negligible in the quiet zone of between ±5^{o} (Henderson-Sellers 1998). This zone is also known as the "equatorial doldrum" (NOAA)and extends to as much as ±10^{o} (Columbia Electronic Encyclopedia), a region within which ancient mariners were trapped owing to the extreme calm for extended periods. The homing device would aim to keep the disc within ±5^{o} latitude of the equator. A steady longitudinal position should be maintained to ~ 1^{o} of each FM's initially deployed position to avoid long term drift toward land masses. One would (1) build into each FM a pumping system that can move it north-south, (2) incorporate a GPS receiver to pinpoint its latitude, longitude, and time, and (3) draw upon the use of nature's easterly and westerly currents near the equator. The latter along with the FM's north-south pump generated movement would be able to achieve positional confinement. In Footnote 2, a fully self-contained system is discussed if the GPS component is temporarily none functional.

Briefly, the FM will be equipped with a pump that can generate movement north or south with velocities of comparable magnitudes to the natural westerly equatorial currents and the easterly counter current. With the GPS location and its change over time, the natural drift velocity is measured. The pumping system is activated to move latitudinally to seek the counter current to restore its longitude. In this manner, a deployed FM can maintain its steady location by "circling" around its deployed position, the size of this FM residence zone would be governed by the extent of the transition zone. Additional details are discussed following description of the propulsion system.

3.1. Propulsion System

Figure 1 provides a detail design of the essential components of a Smart FM. The FM will have embedded permanent magnets such that one axis will be aligned with the earth's magnetic field similar to a compass. An open channel with a water pump will be incorporated in the channel with reversible pumping capability. If the FM is sensed (GPS or built-in sensor described in Footnote 2) to be in the northern hemisphere and substantially outside of the $\pm 5^o$ quiet zone, the pump will suck sea water from its southern port and eject the sea water from its northern port thus pushing the FM southward. A reversed pumping direction when in the southern hemisphere would push the FM northward.

For the propulsion system, it is important to have an estimate of the latitudinal drift velocity that FMs might need to maintain locational stability. The equatorial surface flow velocity in the east-west direction has a mean speed of ~40 cm/sec(Bischoff 2004). The propulsion system should be able to handle a latitudinal push of comparable magnitude, or ~40 cm/sec. This will permit FM crossing over east-west flow boundary to maintain longitudinal position and coincidentally latitudinal confinement. Footnote 3 describes details of the pump system that can provide the required flow capability.

3.2. FM Residence Zone

In keeping the FMs within $\pm 5^o$ of the equator, there is an eastward drift along the NECC (north equatorial countercurrent) of~40 cm/sec (Arnault 1987, Richardson 1984) amounting to ~12 months for crossing the major oceans. Each FM would have longitudinal position information over time and thus its drift velocity. Such information can be used to help an FM utilize its propulsion system to seek the NEC or SEC (north or south equatorial current) to move it westward without hitting land masses. Seeking the boundary between the equatorial current and countercurrent will stabilize each FM longitudinally while staying within the range of $\pm 5^o$ latitudinally. Indeed, the boundary of the northern edge of the SEC and the southern edge of the NECC is between about 3^o and 4^o north of the equator in the Atlantic (Peterson 1991, Bourles 1999). This border may well be the optimum region for the FMs to find its longitudinal stable position. The northern edge of the SEC has a westerly drift of ~30 cm/sec (Bischof and Mariano 2004) comparable to that of the NECC. A historical record of the longitudinal location in its onboard processor will allow an FM in the northern hemisphere to move north if there is an easterly drift or to move south if there is a westerly drift of more than 10 Km from its initial deployment location. For those in the southern hemisphere if the FM is moving westerly, move north. Such a feature would minimize FMs from beaching permitting self-correcting positional operation once its initial longitude is programed just before being thrown overboard. With a transition zone of 1^o to 2^o, and latitudinal velocity matched to that of the longitudinal drift velocity, the residence zone of each FM could be confined to well within 200Km x 200Km.

4. Discussion and Summary

Various ideas for solar radiation management have been proposed over the past decades. None has been implemented partly due to practicality, cost, and management, but primarily due to concerns for termination shock. This proposed approach is not without similar and its own challenges. Despite the latitude pump provided movement and longitudinal stabilization using natural currents facilitating confinement of the mirrors near the equatorial calm zone, there will be wanderers beaching at some shoreline. There needs to be a collection and redistribution system setup for these errant FMs. Waves would reduce solar illumination due to reduced mean cross-sectional inclination.

All climate control programs are expensive, so will the SRM FM proposed. Despite the use of mature unsophisticated technology, the number of needed reflectors will if optimized in size would likely still require many hundreds of billions of dollars for implementation spread over a decade. Components needed for each unit would likely remain relatively constant in cost as size increases. Larger size would reduce total system cost. International cooperation in cost sharing and management will be essential. The proposed approach can be implemented, in stages with small scale testing first before moving towards global implementation.

Significant amount of modeling (Niemeier 2013)has been conducted to assess the interactive effect of anthropogenic forcing and SRM negative forcing. The higher altitude SRM approaches such as space mirrors (Schmidt 2012) and stratospheric sulphate aerosol injections (Kravitz and Robock 2011) tend to result in more global effects, while sea salt injection(Kravitz and Forster 2013) at lower altitudes has varied geographic impact on the hydrologic cycle. We expect the FM approach will be more akin to the sea salt injection scheme in its geophysical hydrologic impact.

On a seasonal basis, equatorial clouds will have an impact on the effectiveness of FM in solar radiation reduction. During winter and summer solstices, the inclined solar radiation due to earth's tilt would actually be reflected specularly back into space avoiding the frequently present equatorial clouds. During the equinoxes, when the sun is directly overhead, the FM's will be less effective in the presence of equatorial clouds. Instead of specular reflection, it would be reflective of the diffuse radiation incident onto the ocean surface reducing radiation absorption by ocean waters.

SRM may be implemented as a step function, on/off, the large thermal mass of the earth will result in a slower temperature response (Schwartz 2007) over many years. There have been concerns with sudden termination of SRM exacerbating GHG mitigation programs (Parker 2018, Robock2008). Such concerns should not be the reason not to seriously consider the added ability for having a separate knob for managing the global climate especially if temperature positive feedback mechanism may thwart GHG mitigation and sequestration.

The initial global deployment could be concentrated within a degree of the equator. However, overtime, the FMs would be dispersed but contained within $\pm 5^o$ due to the longitudinal stabilization feature. These meter sized FMs would not interfere with shipping navigation nor marine life.

Adding or subtracting the number of mirrors is straight forward. However, to implement such an approach will require a concerted effort from all nations financially and logistically. The first step could be the deployment of say a thousand of these mirrors and monitor its performance and dispersion for 1 year. These experimental FMs can be fitted with smart phone technology (not required for ultimate operation) for remote data collection and study. In addition, these initial studies will need to have a component dedicated to investigating the reliability of the FMs. Practically, one would aim for a 99% reliability for at least a 5-year life, i.e., 2 replacements per year per thousand deployed. With initial study success, full implementation will likely take a decade thus spreading cost over an extended period.

Eventual deployment will be between the Prime Meridian and 40^oW on the Atlantic Ocean, 105^oW to 165^oE on the Pacific Ocean, and 50^oE to 90^oE on the Indian Ocean. The deployment longitudinal boundaries will be around 10^o or ~1000 Km from land masses.

Most significantly, the described solar management can provide another method to reduce global temperature slowing down potentially catastrophic climate change especially from potentially unfavorable albedo run away while humanity continues to modify energy consumption habits and technology development into the use of cleaner energy and the implementation of CO_2 mitigation and sequestration. This technology would have an advantage with manageable and practical adjustments via discs thrown overboard or retrieved.

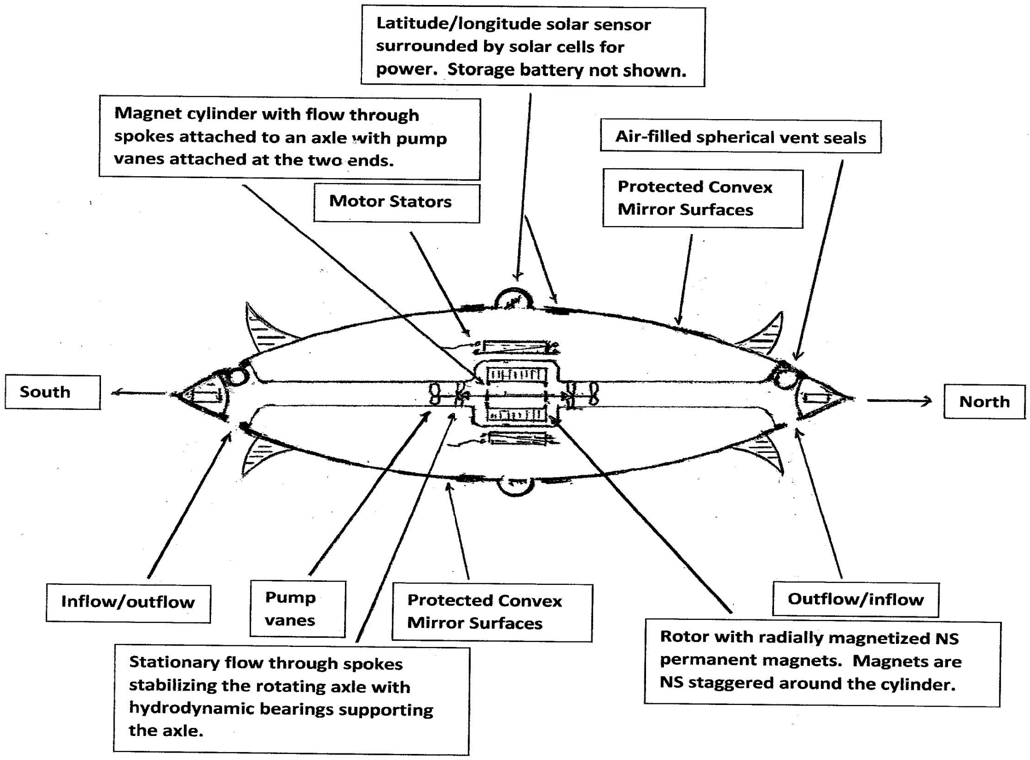

Fig.1 This is a cross-sectional view of the Floating Mirror. All components and functions are labeled on the Figure except for the self-evident set of fins on both surfaces. The two embedded magnets are both aligned N-S so that N-S orientation for the FM is defined.

Footnote 1

The Ice shelf (high albedo) area relative to open water (low albedo) area below the Antarctica circle (67^{o} south latitude) is around a ratio of 2:1 by planimetry. Below the Antarctica Circle, its albedo is highly dominated by the ice shelf especially. During winter solstice, Antarctica contributes 0% to the global albedo. The projected area at the equinoxes is ~1.3% of the total irradiance by the sun. During Antarctica summer solstice, this projected Antarctica circle surface area, accounting for the 23.4^{o} orbital tilt, increases to ~6.1% of that of the earth effectively contributing to a larger percentage of the global albedo. By averaging these four seasons, the annual average Antarctica circle irradiation is ~2.2% of the total illumination of the earth by the sun. 2.2% (percent illumination on Antarctica) x 1360 W/M^{2} (solar irradiance) x 0.1 (albedo decrease) = 3 W/M^{2}. This is equivalent to a potential increase of radiative forcing of ~0.75 W/M^{2} for an Antarctica albedo reduction of 0.1.

Footnote 2

Here, we provide a description of a fully self-contained system if GPS is not part of the system. A miniature solar cell with orientational control will be mounted at the center of each side of the concave surface. A hemispherical transparent dome hermetically protects the solar cell (see Figure 1). A simple cam mechanism is incorporated for mounting the miniature solar cell such that its normal vector to the cell surface can be swept ± 45^{o} on the plane normal to the mirror surface and the N-S axis. The mirror's angular location relative to the solar incidence can be easily determined just by sweeping the cell and finding the maximum signal relative to the mirror's normal axis. Straight forward time averaging will account for FM normal axis variations due to waves. One notes that the magnetic and geometric poles have a relative angle of 9.9^{o}. This angle would be accounted for in the latitude determination. During winter and summer solstices, the orbital angle (ϴ) when tilted towards north or south would indicate a southern or northern hemisphere location respectively.Since the earth has a tilt of ~23.4^{o} relative to the solar orbital plane, location detection relative to the equator will require an embedded internal calendar clock to correct for seasonal variation to the measured ϴ. The earth's tilt would reduce the areal reflection by a mere 8% during winter and summer solstice relative to the equinoxes.

Similarly, the solar east-west angle (relative longitude) can be measured with sweeping along the plane orthogonal to the N-S plane once a day at the same clock time or at other predetermined times. With the relative change in longitude over a 24-hour period or other known time intervals, a drift velocity can be obtained. With its initial deployment longitude and time, the instantaneous longitudinal position can also be recorded. With the acquired latitudinal and longitude information, each FM can be easily localized to within ~1^o with a proper propulsion system taking advantage of the near equatorial currents and counter currents.

Footnote 3

The mirror weight is estimated to be around 10 Kg based on the 1-meter diameter PVC mirror base material and a wall thickness of ~1/2 cm. To maintain FM north-south motion of comparable magnitude, the flow generated momentum need to be ~4x10^5 gm-cm/sec, the pump needs to eject a column of sea water the amount contained in 100 cm, the diameter of the FM, and a flow channel area of 10– 40 cm^2 (~3.6 – 7.1 cm diameter cross section) at a corresponding velocity of ~400 – 100 cm/sec. The flow generated is ~4000 cc/sec. There is little drag on the low-profile FM at these low velocities on seawater (40 cm/sec is around 1 mile/hr). Viscous loss through the channel for the relevant conditions is merely~1mmHg (0.013 pascal). The flow power at 4000 cc/sec required is ~0.5 watt. One would allow for added capacity. A 2-watt system should be able to handle FM drift velocities few folds greater than the mean, and the power needs for other on-board electronics. A small portion of the mirror will in addition have a 5-watt collector (1/3 sqft using standard solar cell technology of 15 W/sqft). Therefore, 3% of the reflector area will be used for solar cells. Such a power system should have ample capability to impart movement to the FMs. A supplementary rechargeable battery will be incorporated to maintain electronic capability at all times. A 50 watt-hr Li-ion battery (~250 gm) will also be capable of operating the pump overnight and overcast days. Power requirement would scale as the surface area of the FMs. The FM configuration and details are described in Footnote 4 and Figure 1.

Footnote 4

In Figure 1, the north-south cross-section of the FM is shown. The body of the FM consists of two identical spherical segments or caps joined along the circular rims of the mirror-image caps. The magnets are aligned diametrically opposite near the rim of the caps. The magnets break the circular symmetry of the FM. The common plane of the caps in which the magnets are imbedded serves as the inversion plane of the FM, the lower half is submerged and the upper half serves as the reflector. Flipping the FM 180^o would result in the same reflector configuration. At the central axis of the caps are located two latitude and longitude sensors which would permit fully self-contained operation in the absence of the GPS. This is provided as a backup design (see Footnote 2). The above air-surface sensor is the active one. Also illustrated are the circularly situated solar cells that power the FM. Colinear with the alignment magnets is a channel with a pump situated at the central region of the FM. Within the channel is the rotor of the pump, its shaft supported by two stationary flow-through spokes (see Figure 1). The motor shaft on which pump vanes are mounted on both ends are supported by a set of conical hydrodynamic bearings (Kung 1997). The complementary bearing surfaces are on the stationary spoke and on the rotating shaft. These sets respectively stabilize the rotor for either direction of flow. Alternating radially poled permanent magnets are circumferentially mounted and embedded hermetically in the PVC cylinder. The rotating cylinder is attached to the shaft via spokes in order to preserve unimpeded flow through the motor body. Circumferential stators to drive the rotor are located outside of the flow channel wall (see Figure 1). The channel splits into two Y-channels before each magnet alignment position. Only the submerged ports would be open as inflow and outflow port. Air-filled "ping-pong balls" serve as valves, sealing off the air exposed ports allowing for sea water to be pumped in the appropriate direction generating the proper propulsion flow. The required technology hardly stretches pump technology. Since little pressure head needs to be generated, and the desired reversible flow direction, the pump vanes should be perpendicular to the axial hub over their entire span but inclined to the flow direction with characteristic dimension of ~1 – 2 cm. Six to ten vanes fitted around the hub rotating at 3000 to 10,000 RPM would be able to generate the desired flow of ~4000 cc/sec. A set of built-in fins at the pump ports would prevent FM spinning while maintaining north-south alignment during FM latitudinal movement under pump action. The needed processor can be designed with specific functional needs incorporating GPS receiver chip and location memory, latitude and longitude determination, pump motor speed control, battery charge and discharge. ASIC (application specific integrated circuit) technology could be well suited for such application at very low cost.

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