The Increasing Need for Research on Geoengineering Approaches to Reducing Potential Global Cooling

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Executive Summary

Interest in geoengineering has been centered on the possibility of substituting it for reductions in greenhouse gas (GHG) emissions widely promoted as a solution to hypothesized global warming/climate change. Although it would undoubtedly be both more effective and cost-effective than GHG emission reductions, a more fundamental question needs to be answered before geoengineering is seriously considered: Is it likely to be needed and under what circumstances? This article explores the likely causes, primarily astronomical in nature, of climate change, summarizes new observationally-based forecasts of future global temperatures based on amazingly accurate hindcasts over the Holocene, and then uses these forecasts, as well as previous knowledge of ice age cycles, to suggest when geoengineering might be useful in avoiding climate destabilization. It concludes that astronomical climatology can play a vital role in applying geoengineering solutions to achieve climate stabilization by highlighting future climate changes that the residents of Earth may decide they want to try to avoid or changes that are not consistent with Holocene-based expectations that may lead to a new and catastrophic ice age.

Acronyms Used

AGW: Anthropogenic global warming
CSF: Climate sensitivity factor
CO_2: Carbon dioxide
GHG: Greenhouse gas
IA: Ice Age
IPCC: Intergovernmental Panel on Climate Change
LIA: Little Ice Age
NAO: North Atlantic Oscillation
PDO: Pacific Decadal Oscillation
SRM: Solar Radiation Management

Purpose—To Answer These Questions

This paper explores the following issues:
—Under what circumstances might geoengineering be useful?
—How likely are these circumstances?

—Is geo the only approach that might be able to stabilize the Earth's climate under these circumstances?

—Is there a geo option that might work under these circumstances?

—What needs to be done to advance geoengineering under these circumstances?

The Causes, History, and Likely Future of Climate Change

In order to understand the potential usefulness of geoengineering approaches to climate stabilization, it is important to first understand the history, causes, and likely future of climate change so as to understand what it is that we may want to stabilize. The first section of this paper will be devoted to this purpose.

The AGW view of climate change is much like the pre-Copernican view of the Earth's place in the Universe since it largely ignores the role of astronomical influences on climate. In addition to the important question of the scientific validity of the AGW hypothesis discussed in (Carlin, 2011), it is evident that the Earth has had a continuing series of climate changes, often of a fairly regular or cyclical character, over its long history and well before humans caused an increase in GHG emissions. So there must be some other cause or causes for some or all of these climate changes the Earth has undergone.

A likely hypothesis is that climate change is determined by a very complex interaction of many influences, primarily but not entirely astronomical in nature. If so, and because of the cyclical regularities of astronomical influences, it is probable that they can best be understood by applying cyclical analysis to climate and solar data. Climate model results used by the IPCC do not include the effects of solar cycles on oceanic cycles and global temperatures but these cycles plainly exist—and have major similarities.

This alternative view, which has a long academic history,* argues that the Earth's climate is primarily influenced by variations in our source of light and heat, the Sun. Further, there is increasing evidence that variations in the Sun, in turn, may be due to the tidal effects of the movement of the planets, particularly the two largest, Jupiter and Saturn, on the Sun. I will refer to this area of research as astronomical climatology and may involve the influence of the Moon, the planets, the Sun, and the cosmos on the Earth's climate. This approach has been criticized, but Scafetta (2012) believes that he has now satisfied these concerns and has furthermore shown how such an approach can explain much of the data collected over several centuries as to variations in the

* *Scafetta (2012) states: "An alternative theory has been proposed and studied since the 19th century and it was originally advocated even by well-known scientists such as Wolf (1859), who named the sunspot number series. This thesis was also advocated by many solar and aurora experts (Lovering et al., 1868) and by other scientists up to now (Schuster, 1911; Bendandi, 1931; Takahashi, 1968; Bigg, 1967; Jose, 1965; Wood and Wood, 1965; Wood, 1972; Dingle et al., 1973; Okal and Anderson,1975; Fairbridge and Shirley, 1987; Charvatova, 1989, 2000, 2009; Landscheidt, 1988, 1999; Hung, 2007; Wilson et al., 2008; Scafetta, 2010; Wolff and Patrone, 2010; Scafetta, 2010, 2012, submitted for publication)."*

Sun and global temperatures. Since the IPCC has stated that one of the reasons they favor the AGW approach is that they cannot think of another explanation for the observed temperature changes, this alternative explanation offers an important alternative to the AGW hypothesis that undercuts this particular IPCC argument and calls into question their judgment. Although the data for the period prior to written solar observations is limited, there have been a wide variety of observations concerning the varying number of sunspots, the length of sunspot cycles, and temperatures which all need to be explained if we are to understand past and future climate changes which might or might not be usefully offset by future geoengineering.

Scafetta (2012) summarizes his very recent findings in this regard in part as follows:

The Schwabe frequency band of the Zurich sunspot record since 1749 is found to be made of three major cycles with periods of about 9.98, 10.9 and 11.86 years. The side frequencies appear to be closely related to the spring tidal period of Jupiter and Saturn (range between 9.5 and 10.5 years, and median 9.93 years) and to the tidal sidereal period of Jupiter (about 11.86 years). The central cycle may be associated to a quasi-11-year solar dynamo cycle that appears to be approximately synchronized to the average of the two planetary frequencies. A simplified harmonic constituent model based on the above two planetary tidal frequencies and on the exact dates of Jupiter and Saturn planetary tidal phases, plus a theoretically deduced 10.87-year central cycle reveals complex quasi-periodic interference/beat patterns. The major beat periods occur at about 115, 61, and 130 years, plus a quasi-millennial large beat cycle around 983 years. We show that equivalent synchronized cycles are found in cosmogenic records used to reconstruct solar activity and in proxy climate records throughout the Holocene (last 12,000 years) up to now. The quasi-secular beat oscillations hindcast reasonably well the known prolonged periods of low solar activity during the last millennium such as the Oort, Wolf, Sporer, Maunder, and Dalton minima, as well as the 17, 115-year long oscillations found in a detailed temperature reconstruction of the Northern Hemisphere covering the last 2000 years. The millennial three-frequency beat cycle hindcasts equivalent solar and climate cycles for 12,000 years. Finally, the harmonic model herein proposed reconstructs the prolonged solar minima that occurred during 1900–1920 and 1960–1980 and the secular solar maxima around 1870–1890, 1940–1950 and 1995–2005 and a secular upward trending during the 20th century: this modulated trending agrees well with some solar proxy model, with the ACRIM TSI satellite composite and with the global surface temperature modulation since 1850. The model forecasts a new prolonged solar minimum during 2020–2045, which would be produced by the minima of both the 61- and 115-year reconstructed cycles. The model predicts that during low solar activity periods, the solar cycle length tends to be longer, as some researchers have claimed. These results clearly indicate that both solar and climate oscillations are linked to planetary motion and, furthermore, their timing can be reasonably hindcast and forecast for decades, centuries and millennia…

There appear to be several similar cycles involving planetary motion, sunspot cycles, oceanic oscillations, and global temperatures (Scafetta, 2010,

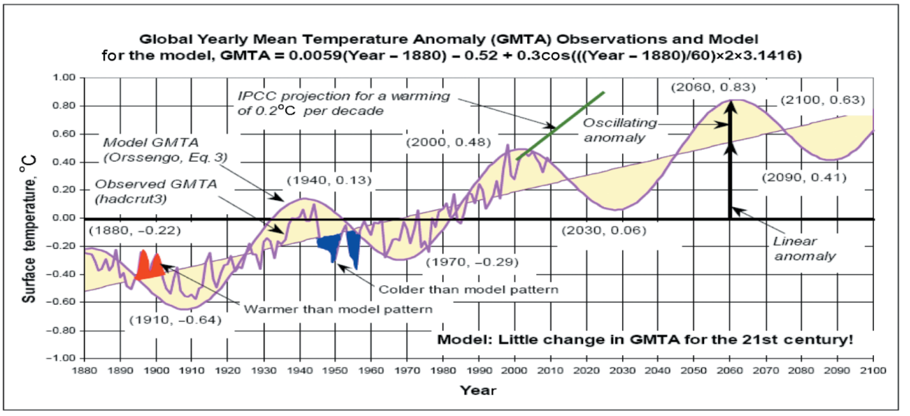

Fig. 1. 60-year Cyclical Envelope Model that fits last 130 years. Based on (Orssengo, 2010).

2011). An interesting hypothesis is that planetary motions determine tidal forces on the Sun, sunspot cycles, and solar variability, which directly or indirectly influence oceanic cycles, which influence global temperatures and climate change. The Svensmark hypothesis explains one way solar variability may influence cloud formation and thus temperatures. The possibility of this mechanism was recently confirmed by CERN experiments (Kirkby et al., 2011). IPCC climate model results do not show effects of solar cycles on oceanic cycles and global temperatures but these cycles plainly exist—and have major similarities. All this suggests an astronomical origin of some or all temperature cycles.

These solar/temperature cycles can usefully be divided between those less than 1000 years in length and those greater. Scafetta (2012) concerns the ones less than 1000 years and will be summarized first. The temperature cycles exhibited by the cyclical ice ages of 100,000 years that Earth has experienced over the last million years have long been attributed to astronomical phenomena but need further research if they are to be fully understood, and will be discussed second.

The two clearest shorter temperature cycles are the 60/61 and 1000/983 year ones. The 60 year can be readily seen in the recent historical record (Fig. 1), as can an approximate 1000 year cycle in the Northern Hemisphere temperature record (see Fig. 2). Figure 1 shows a 60-year temperature cycle superimposed on a gradually increasing temperature trend over the last 130 years which appears to fit most of the data over the period. Note that the trend line appears to have existed since the end of the LIA, well before significant GHG emissions. The gradually increasing trend line may be primarily a manifestation of the current upward phase of the 1000-year cycle since the trend evidently did not exist prior to the LIA. The 60-year PDO and NAO may well be manifestations of the important 60-year solar cycle.*

* *In the case of the NAO see (Mazzarella and Scafetta, 2011).*

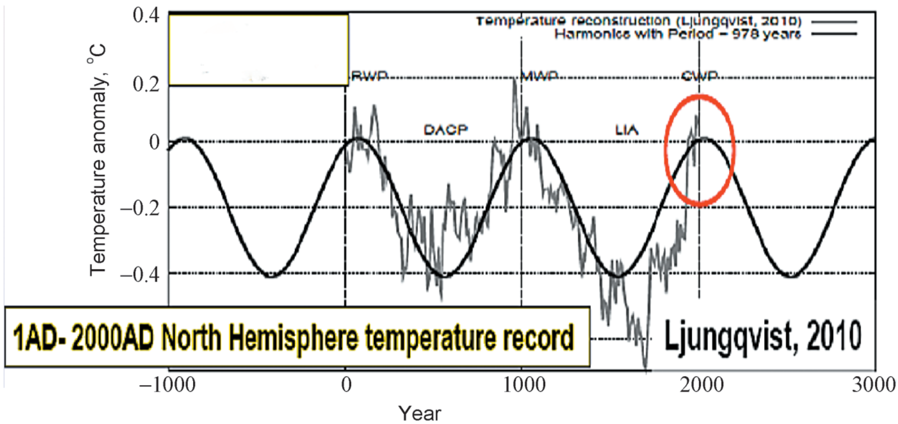

Fig. 2. Likely ~1000-year temperature cycle. Based on (Scafetta, 2011).

Unlike the AGW/IPCC hypothesis that with a few exceptions, such as volcanic eruptions, there is no other explanation for climate change other than AGW, it is clear that some appropriate combination of these cycles might explain the Earth's climate changes over at least the Holocene.

Figure 3 shows how Scafetta's model fits with two temperature proxies (Bard et al., 2000 and Steinhilber et al., 2009) and his 983-year cycle.

Figure 4 shows how the Northern Hemisphere temperatures fit with his model and the 115-year cycle. This figure suggests that the 115-year cycle also plays an important role. Whether or not Scafetta's exact parameters are improved by further research (he states that he has made a number of simplifying assumptions, which suggests that refinements are possible and even likely), the important thing is that a solar-planetary explanation for climate change shows much more promise than the AGW hypothesis. The ability to hindcast millennia of the limited Holocene climate data we have is something that AGW adherents can only dream about.

Figure 5 shows Scafetta's reconstruction and forecast (Scafetta, 2012) from 1800 to 1850. In highly simplified form, Scafetta appears to believe that temperatures will roughly continue up the trend line shown in Fig. 1 with the same 60-year cycles around the trend line until the peak of the 983-year cycle, which he expects in 2060. He does comment, however, that the valley in the 2030s may be particularly deep given the coincidence of the 60- and 115-year minimums. This will presumably be counteracted, however, by the 130-year cycle which should have a maximum about that same time period, but which Scafetta regards as a weaker cycle, as well as the still rising 983-year cycle.

In his temperature reconstructions and forecasts, the forecasts are substantially below those projected by the IPCC (see particularly the area between the dashed and solid blue lines in Fig. 13 of (Scafetta, 2011), which represents his current views, compared to the IPCC range shown well above this area, and the divergence between the red and green lines shown in Fig. 1 above).

Figure 6 shows the last five interglacials aligned on the peak temperature reached based on Vostok ice cores. The Holocene is thus far similar to three of

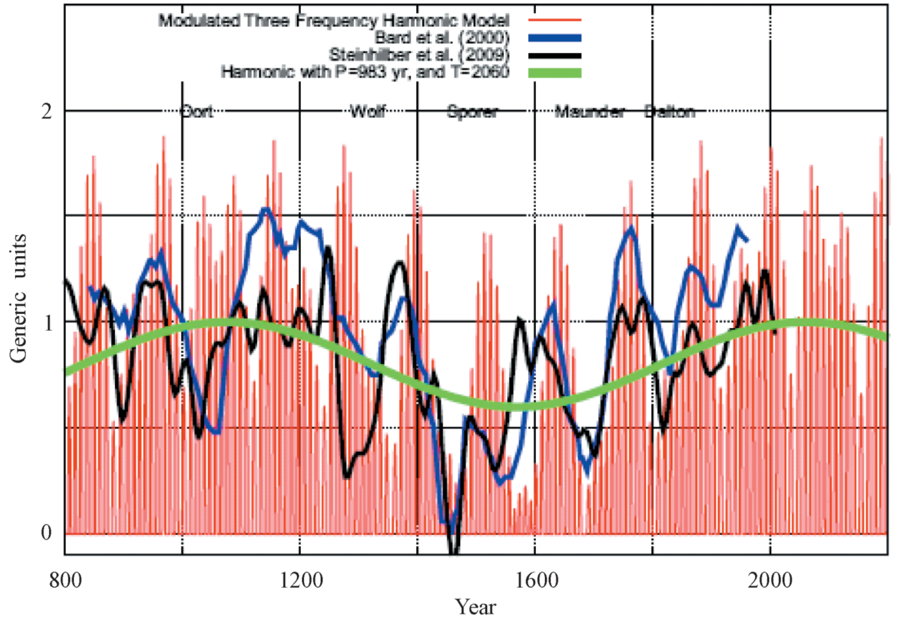

Fig. 3. From (Scafetta, 2012).

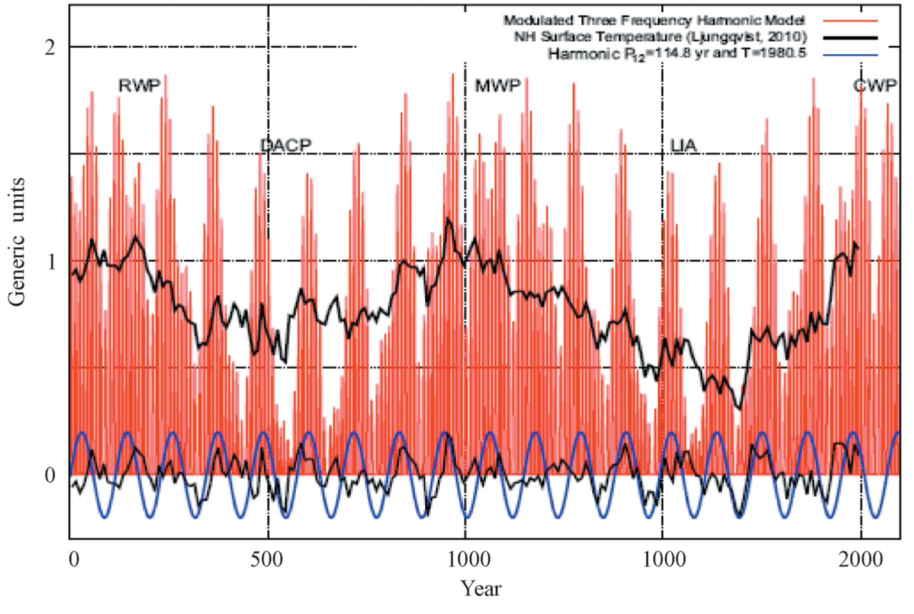

Fig. 4. From (Scafetta, 2012).

the four previous interglacials. If the Holocene ends up being like the previous one, the Eemian, we may have up to 3000 years before the next ice age starts; if not, it could start sooner.

Figure 7 presents summary information concerning the geo implications of astronomical cyclical analysis. The bottom four lines show a number of the

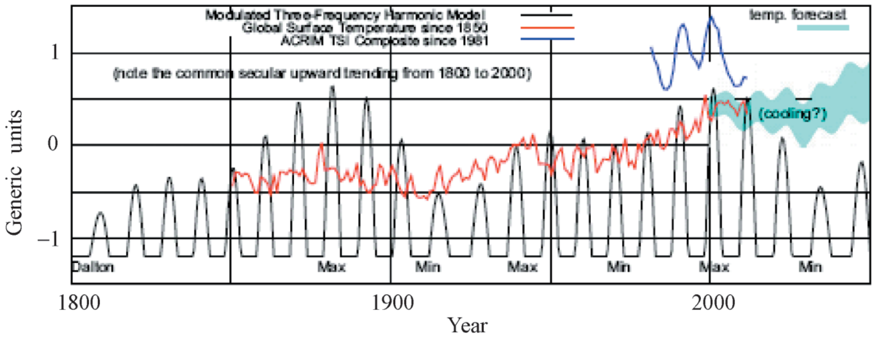

Fig. 5. From (Scafetta, 2012).

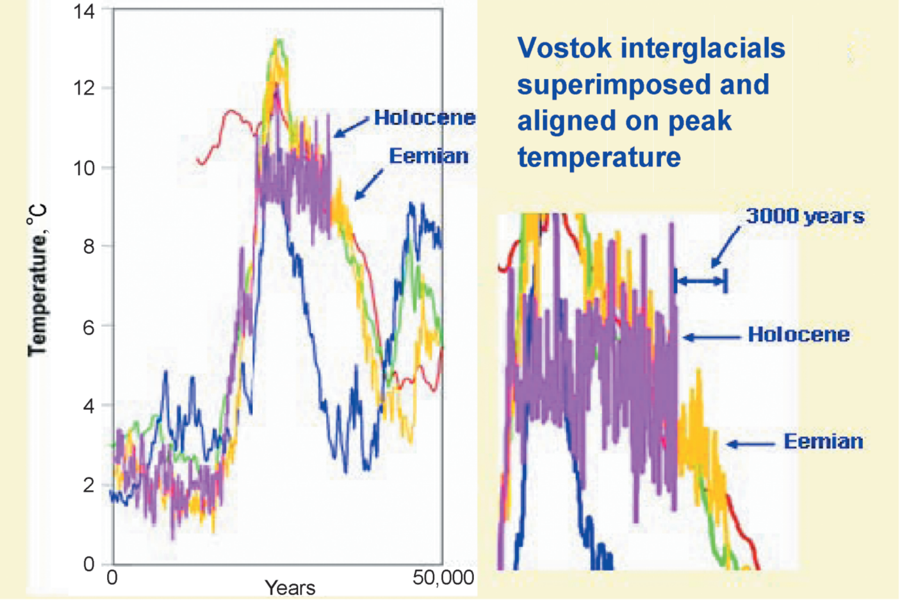

Fig. 6. From (Archibald, 2008).

cyclical parameters for the cycles used by Scafetta (2012) in his model. The top line presents my guesstimates of similar parameters for the next ice age since there has also been an important 100,000-year ice age cycle over the last million years.

Sources for Fig. 7: The 100,000-year cycle peak is based on Imbrie (1986), p. 179; the valley is assumed to be 50,000 years from the peak, although Imbrie states that the maximum glacial advance is expected 23,000 years from now (p. 181); the amplitude is my guesstimate based on Fig. 6 above. All other amplitudes and dates are from Scafetta (2012) except that the amplitudes of the 61- and 983-year cycles are my guesstimates based on the middle graph of Slide 12 of Scafetta (2011) and Fig. 2 in this paper, respectively.

What all this suggests is that astronomical climatology appears to provide useful information as to circumstances when geoengineering might and might

Years	~Amplitude °C	Estimated Peak/ Valley in Cycle	Need for Geo to Avoid
100,000 (ice age)	~7	~4,500 BC/~45,000 AD	Yes, particularly for high latitudes. New ice age catastrophic
1,000/983	~0.4	2060/2550 AD	Perhaps after ~2300
130	Weaker	2035/2100	Not in itself
115	~0.1	1981/2038	Doubtful but next minimums combined
61	~0.2	2001/2033	

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Fig. 7. Some significant global temperature cycles and geo implications.

not be useful. In the case of the parameters assumed in Fig. 7, these circumstances include the 100,000-year ice age cycle and possibly the 983-year cycle so as to avoid a recurrence of a new Little Ice Age. Obviously, a new ice age would be catastrophic to civilization as we know it. But a LIA would also be quite damaging and might be worth considerable efforts to avoid if we can understand when it might occur and create a realistic plan to overcome it.

Why Geo Is the Only Realistic Possibility to Achieve Climate Stabilization

Climate is a very complicated system, but the observationally-based evidence presented above suggests global temperatures may be headed down until the 2030s—and sooner or later way down either as a result of a downturn in the 983-year cycle or the 100,000-year ice age cycle, which is coming due within the next few millennia. To avoid future adverse climate changes by adjusting CO_2 emissions we would have to accurately predict changes far in advance since ambient CO_2 levels change only slowly and uncertainly (Carlin, 2007a and 2008). Given the bad record to date in predicting temperature changes based on increases in CO_2, it would seem extremely unlikely that such an approach would result in climate stabilization even if the world could agree on the very costly measures necessary to implement it. In addition, controlling cooling would require *increasing* GHG emissions, which might be particularly difficult for environmentalists to accept. Major uncertainties include the following: climate sensitivity, implementation, CO_2 residence time, and fossil fuel use. We need the capability to respond rapidly (maybe as little as one year given evidence that ice ages sometimes start very rapidly) to any real threat of major adverse change as long as the future remains uncertain. Geo offers the only real opportunity for this despite problems that a number of academics have raised. Attempting to use the hypothesized relationship between CO_2 levels and temperatures is uncertain at best and too slow to accomplish the changes that might be needed even if the uncertainty disappeared.

SRM using insertion of appropriate particles in the stratosphere could rapidly increase or decrease global or possibly even regional temperatures as needed—clearly what will be needed if humans wish to actually achieve climate stabilization. This could be done by individual countries or groups of countries, but would best be done under international agreements (Carlin, 2007). SRM would be very much more effective than attempts to vary CO_2 emissions. It would also be much more efficient compared to CO_2 reductions to bring about global cooling, specifically:

—by ~4–5 orders of magnitude in terms of cost-effectiveness in marginal cost/ton C-eq. using IPCC assumptions concerning CSF and CO_2 residence times ((Carlin, 2011), p. 1014 and Table 2).

—by ~6–7 orders using observation-based CSF and CO_2 residence times ((Carlin, 2011), p. 1017).

So IF attempting to control for warming, it is MUCH better economically to use SRM since CO_2 increases are probably hopeless to bring about warming. SRM has numerous problems/risks, of course, which have been widely discussed in the literature. I believe it should be a presumed priority for research and the construction of an international system to implement if and when needed. High latitude countries, however, have a self-interest in spearheading effort to prevent cooling since cooling will hit them most and with greater effect.

When Should Geo Be Considered for Preventing Cooling?

As discussed above, I believe that geoengineering should only be considered for potentially catastrophic changes (not those likely to be caused by AGW) such as a new IA or possibly a new LIA. The 100,000-year IA cycle has existed for about a million years. The next IA will undoubtedly bring huge costs from a major temperature fall and accompanying ice buildup in the higher latitudes. The important questions are can we tell when it starts and would geo be sufficient to avoid it? Although geo is much more tolerant than CO_2 control to a lack of understanding of the basic causes of climate change, it may nevertheless be difficult to distinguish between the start of a new ice age and an unusually cold period or even an unexpectedly cold year or two. But it is vital that this occurs if geoengineering is to be effective in preventing climate destabilization. This in turn requires a greatly improved understanding of the expectations for "normal" climate so that the "abnormal" process of IA initiation can be recognized quickly and accurately and in time to decide to use geoenginering before the albedo effect takes over. Or if residents of Earth should decide that they do not want to endure another LIA but are willing to endure any adverse effects of geo, advance knowledge of a prospective LIA would provide the information needed to make a decision to implement appropriate geo. The study of astronomical climatology can play an important role in both cases.

If IAs are in considerable part a result of the ice albedo effect there might be hope for successful intervention—by decreasing the ice build up very early in the process and thus possibly avoiding or at least decreasing the feedback effect of the build up. But there are still many questions, including the following:

—How much of a decrease in temperatures below those predicted by Holocene-based astronomical climatology is needed to initiate an IA?

—Are there other factors leading to IA initiation that would make it difficult to successfully use geo for IA prevention?

Answers to the Original Questions

At the beginning of this article I posed several questions. The analysis suggests the following answers:

—Under what circumstances might geo be useful? Avoiding a new IA; possibly avoiding another LIA.

—How likely are these circumstances? Almost certain as a result of the 983- and particularly the 100,000-year cycles.

—Is geo the only approach that might be able to control the Earth's climate under these circumstances? Yes.

—Is there a geo option that might work under these circumstances? Yes, SRM.

What Needs to Be Done

I believe this analysis leads to the following conclusions as to what needs to be done:

1. Better understanding of astronomical climatology and ice age initiation to more easily recognize IA/LIA initiation as early as possible.
2. Detailed laboratory/computer studies to determine the best means, environmental effects, and detailed costs to implement an optimum geo approach such as SRM when it proves to be necessary.
3. Very limited testing of the optimum approach to verify its key parameters without endangering the Earth's environment. An initial effort was made by the Institute of Global Climate and Ecology of the Russian Federation in 2008/09.
4. Development of an international understanding and mechanism for quickly implementing the optimum approach when and if determined to be actually needed to avoid very adverse climate changes (not normal or minor variability). The results from research on item 1 above should provide additional insight as to when this might be needed, but it may take a long time to develop given the vicissitudes of international diplomacy and would require a substantial change in current diplomatic efforts concerning climate change.

References

Archibald D., 2008. Solar Cycle 24: Implications for the United States, International Conference on Climate Change, March, available on-line at http://www.davidarchibald.info/papers/Solar%20Cycle%2024%20-%20Implications%20for%20the%20Unites%20States%20David%20Archibald%20March%202008.pdf.

Bard F. E., Raisbeck G., Yiou F., and Jouzel J., 2000. Solar irradiance during the last 1200 years based on cosmogenic nuclides, Tellus, vol. 52B, pp. 985–992.

Carlin A., 2007. Implementation and utilization of geoengineering for climate change control, Sustainable Development Law and Policy, vol. 7, No. 2, Winter, pp. 56–58, available on-line at http://www.carlineconomics.com/files/pdf/CarlinSustainableDevelopment.pdf.

Carlin A., 2007a. Climate change control: Is there a better strategy than reducing greenhouse gas emission, University of Pennsylvania Law Review, vol. 155, No. 6, June, 1401–97, available on-line at http://pennumbra.com/issues/article.php?aid=138.

Carlin A., 2008. Why a different approach is required if global climate change is to be controlled efficiently or even at all, Environmental Law and Policy Review, vol. 32, No. 2, Spring, pp. 685–757, available on-line at http://www.carlineconomics.com/files/pdf/CarlinWhy.pdf.

Carlin A., 2011. A multidisciplinary, science-based approach to the economics of climate change, Int. J. Environ. Res. and Public Health, vol. 8, No. 4, April 1, pp. 985–1031, available on-line at http://www.mdpi.com/1660–4601/8/4/985/pdf.

Floor A. J., 2010. Water, Ice, and Vapour, The Capricious Role of Water, available on-line at http://www.seafriends.org.nz/issues/global/climate2.htm.

Imbrie J. and Palmer Imbrie K., 1986. Ice Ages, Solving the Mystery, Harvard University Press.

Ljungqvist F. C., 2010. A new reconstruction of temperature variability in the extra-tropical Northern Hemisphere during the last two millennia, Geografiska Annaler: Series A, 2010, 339–50, available on-line at http://agbjarn.blog.is/users/fa/agbjarn/files/ljungqvist-temp-reconstruction-2000-years.pdf.

Mazzarella A. and Scafetta N., 2011. Evidences for a quasi 60-year North Atlantic Oscillation since 1700 and its meaning for global climate change, Theoretical and Applied Climatology, available on-line at http://www.fel.duke.edu/~scafetta/pdf/Mazzarella-%20Scafetta-60-yr.pdf.

Orssengo G., 2010. Predictions of global mean temperatures and IPCC projections, Icecap, April, available on-line at http://wattsupwiththat.files.wordpress.com/2010/04/predictions-of-gmt.pdf.

Kirkby J. et al., 2011. Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation, Nature, vol. 476, pp. 429–433.

Scafetta N., 2010. Empirical evidence for a celestial origin of the climate oscillations and its implications, J. Atmos. and Solar-Terr. Phys., vol. 72, pp. 951–970, available on-line at http://www.fel.duke.edu/~scafetta/pdf/scafetta-JSTP2.pdf.

Scafetta N., 2011. Climate Oscillations and Their Solar/Astronomical Origins: Climate Reconstruction and Forecast, available on-line at http://www.scribd.com/doc/60571419/Nicola-Scafetta-ICCC6-PPT.

Scafetta N., 2012. Multi-scale harmonic model for solar and climate cyclical variation throughout the Holocene based on Jupiter-Saturn tidal frequencies plus the 11-year solar dynamo cycle, J. Atmos. and Solar-Terr. Phys., in press, doi: 10.1016/j.jastp. 2012.02.016, available on-line at http://wattsupwiththat.files.wordpress.com/2012/03/ scafetta_jstides.pdf.

Steinhilber F., Beer J., and Frohlich C., 2009. Total solar irradiance during the Holocene, Geophys. Res. Lett., vol. 36, L19704.