Geoengineering on Exoplanets

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Abstract

Solar radiation management (SRM) geoengineering can be used to deliberately alter the Earth's radiation budget, by reflecting sunlight to space. SRM has been suggested as a response to Anthropogenic Global Warming (AGW), to partly or fully balance radiative forcing from AGW [1]. Approximately 22% of sun-like stars have Earth-like exoplanets[2]. Advanced civilisations may exist on these, and may use geoengineering for positive or negative radiative forcing. Additionally, terraforming projects [e.g. 3], may be used to expand alien habitable territory, or for resource management or military operations on non-home planets. Potential observations of alien geoengineering and terraforming may enable detection of technologically advanced alien civilisations, and may help identify widely-used and stable geoengineering technologies. This knowledge may assist the development of safe and stable geoengineering methods for Earth. The potential risks and benefits of possible alien detection of Earth-bound geoengineering schemes must be considered before deployment of terrestrial geoengineering schemes.

Keywords

Geoengineering, exoplanet, solar radiation management

1 Introduction

Geoengineering is defined [1] as 'the deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming'. SRM schemes include marine cloud brightening using saltwater aerosols [4]; and stratospheric sulphur aerosols [5]. SRM offers rapid control of the Earth's radiation budget by reflecting incoming short-wave radiation, whilst having a disproportionately lower effect on outgoing long-wave radiation [1]. By contrast, carbon dioxide removal methods are much slower-acting, and act principally on outgoing long-wave radiation[1].

1.1 Alien Climate Change and Geoengineering Innovation

It is possible that technological civilisations commonly and/or exclusively emerge on planets with features similar to those of Earth. These may include: tectonic processes, liquid water oceans, and hence biogeochemical cycling similar to that of Earth. Furthermore, delayed evolution of decomposers capable of digesting larger plants, and oceans subject to anoxic events, may tend to cause fossil fuel reserves to appear on such planets in useable quantities and concentrations. Alien civilisations may therefore routinely encounter significant fossil fuel reserves, and may cause CO_2

pollution from combustion of these resources. This pollution may accumulate for decades or centuries before the risks are discovered. With a hydrological cycle similar to that of Earth, and tectonic processes, it is likely that a technological civilisation will also experience volcanism. Planets with a significant biogeochemical sulphur cycle may be predisposed to volcanic sulphur injections into the atmosphere, which may affect the climate in a manner similar to that on Earth – i.e. by causing cooling on annual timescales. This is particularly the case if eruption ceilings penetrate the stratosphere of alien planets. (Other biogeochemistries may also be possible.) Similarly, tropospheric sulphur injections from combustion of fossil fuels may be expected. The above processes will be locally observable, and will eventually lead to knowledge of sulphur aerosol geoengineering. Likewise, a knowledge of cloud processes may lead alien civilisations to attempt to manipulate water clouds, conducting the equivalent of cirrus stripping [6] or marine cloud brightening [4] processes. Whether to counter climate change from fossil fuels or not, it is to be expected that a proportion of alien civilisations with biology similar to our own, and biogeochemistry similar to that of Earth's, will ultimately attempt geoengineering in a form which would be recognisable to us. As an 'anthropogenic' planetary-scale process, this may be one of the most observable signs of an alien civilisation.

1.2 Alternative use cases

By contrast to the global warming use case discussed above, and similar schemes, there exist alternative use cases. It can be imagined that a proportion of alien civilisations may emerge on planets with far more challenging climates than Earth's. Many observed planets orbit binary star systems[7] (as depicted on 'Tatooine' from 'Star Wars'). Extreme Milanchovic cycles [8] could give unpredictable seasons (as depicted in 'Game of Thrones'). Elliptical orbits, or high axial tilt may give extreme seasons, possibly subjecting alien life to long periods of frozen suspended animation. Erratic volcanism may also be climatologically problematic. Alternatively, exoplanets may have permanently small habitable areas, with ice caps or deserts covering much of the planet – giving potential for terrestrial territorial expansion through geoengineering.

Geoengineering may be weaponised for use on aliens' home planets or beyond - deliberately and suddenly changing the climate so as to damage or destroy an enemy civilisation or biosphere. As a further alternative, terraforming use may be widespread, to expand the range of an alien civilisation. It should be considered that these 'hostile' or 'terraforming' uses of geoengineering may be the most detectable forms – as a geoengineering program capable of destroying or re-formatting a target biosphere may give a very large and sudden change in signal, potentially far greater than may typically be expected from an AGW use-case.

2 Geoengineering detection

Below is presented discussion of methods of detecting, analysing and interpreting the climates and potential associated geoengineering schemes of exoplanets. Later, a consideration of the implications of the risks and opportunities arising from these possible detection events is offered.

2.1 Observing Planets

Planetary day, season, albedo and temperature can potentially still be inferred, allowing modelling of climates[9] and clouds[10]. Scattering of light in the atmospheres by aerosols can potentially be measured with spectropolarimetry[11]. All such measurements will tend to be more challenging on small, Earth-like planets than on gas giants. Assuming our solar system is a representative planetary system, the small, rocky and potentially habitable planets orbiting close to their stars will be inherently far more difficult to spatially resolve than larger and/or more distant gas giants.

2.2 Transit Spectroscopy

The James Webb space telescope can potentially be used to detect industrial pollution in alien atmospheres[12]. Development of this method may allow detection of supergreenhouse geoengineering gases [suggested in 3]. Exoplanet atmospheres can be studied using spectrophotometry [13] via the transit method. This technique may allow detection of greenhouse gases (e.g. halocarbons[3]) or possible aerosol precursors, which may have a geoengineering purpose.

2.3 Exoplanet Cloud Cover & Manipulation

Clouds and aerosols can be inferred by observing rainbow-like scattering[10], or polarisation effects[14]. Cloud manipulation[4,6] has been proposed for geoengineering, and may possibly be detectable. However, the highly-differentiated refractive properties of non-water aerosols (when compared to water) will probably render these a more suitable target for detection than are potentially small changes in levels of cloud condensation nuclei, or in the cloud droplets and clouds they affect.

2.4 Time-series analysis

Various astronomical and planetary processes can only be well understood by aggregating data from various data points, at different stages of a life cycle. These disparate examples can then be synthesised into a coherent model life cycle. This technique is used for reconstructing everything from the fate of stars to the development processes of fossil animals. Assuming a large number of alien civilisations emerging on exoplanets, it is reasonable to assume that there is a significant probability of common patterns of development emerging. For example, it is possible that land-based, fire-using, dextrous aliens are the only type capable of building a technological civilisation; and thus small, rocky planets with active carbon cycles are the only places where advanced alien civilisations occur. If correct, it may be expected that ‘anthropogenic’ global warming is also common on other planets. Thus, a time series reconstruction of these predictable patterns of development may reveal frequent geoengineering similar to that which may be deployed on earth. By making such observations, predictions of the likely development and fate of the geoengineering technologies themselves may be possible.

3 Discussion - Implications for Earth

By observing potential alien geoengineering schemes, clear evidence of the existence of alien civilisations may be obtained. Furthermore, successful geoengineering approaches may potentially be ‘reverse engineered’ for use on Earth. Humanity may therefore be able to derive safe technologies and deployment patterns for terrestrial adoption, essentially ‘stealing’ alien geoengineering designs.

It should be remembered that pollution in general, and geoengineering in particular, may betray our technological civilisation to other civilisations in the Milky Way. Likewise, alien civilisations may routinely use skyscanning for geoengineering operations as a way of identifying developing civilisations. This may foster peaceful communications between planets. However, it may also be used as a sign of an emergent threat, triggering the occupation or destruction of the developing planet. If it were found that a proportion of detected geoengineering schemes ended suddenly or chaotically, a military cause for this termination would need to be investigated. Assuming a single aggressor planet and a constant speed of travel, it may even be possible to determine the location of a hostile civilisation by time-series analysis. The time between geoengineering switch-on and the destruction of the host planets or biospheres could potentially be used to triangulate the attacking civilisation's position.

4 Conclusions

Detection of positive radiative forcing by means of detection of 'super greenhouse' gases has been determined to be feasible. Determination of the intent of such releases is not certain, although a time-series analysis or reconstruction may be informative.

Detection of negative radiative forcing from sulphate or other aerosols is more challenging, but spectropolarimetery may ultimately permit the modelling of geoengineered clouds and atmospheres, based on observed data. Again, time series analysis and reconstruction will be necessary, in order to establish a likely technological origin for any aerosol pattern.

Confident determination of any individual geoengineering scheme will be difficult, but analysis of a large number of possible signals, plus a time-series analysis, may suggest a pattern of deliberate climate interventions across the galaxy.

Observation of the evolution of geoengineering technologies may well yield information on the reasons, patterns, timing, stability and obsolescence of observed technologies. This is likely to be instructive in the debate on deployment of such technologies on Earth. If this process is conducted successfully, it may become the first example of interplanetary technology transfer.

Consideration should be given to the possibility of detection of alien geoengineering schemes in the design of future missions. Existing missions should have data analysed with reference to the possibility of detection of alien geoengineering. Any data gleaned by the above methods should be considered carefully in the design and deployment of terrestrial geoengineering schemes.

Finally, consideration of the risk of detection should be given before any terrestrial scheme is initiated, particularly with respect to the possibility of a military attack by an alien civilisation with vastly superior technology to that of mankind. However, this would need to be balanced with any extant risk from other detectable forms of pollution or transmission, which may already expose Earth to similar risks.

References

1. Royal Society (September 2009). Geoengineering the Climate: Science, Governance and Uncertainty (Report). p. 1. ISBN 978-0-85403-773-5

2. Petigura, E. A.; Howard, A. W.; Marcy, G. W. (2013). "Prevalence of Earth-size planets orbiting Sun-like stars". Proceedings of the National Academy of Sciences 110(48): 19273. arXiv:1311.6806. Bibcode:2013PNAS..11019273P.doi:10.1073/pnas.1319909110

3. Gerstell, M. F.; Francisco, J. S.; Yung, Y. L.; Boxe, C.; Aaltonee, E. T. (2001)."Keeping Mars warm with new super greenhouse gases". Proceedings of the National Academy of Sciences 98 (5): 2154–2157. doi:10.1073/pnas.051511598

4. Latham, J. (2002). "Amelioration of global warming by controlled enhancement of the albedo and longevity of low-level maritime clouds". *Atmospheric Science Letters* **3** (2–4): 52. doi:10.1006/asle.2002.0048

5. Robock, A., A. Marquardt, B. Kravitz, and G. Stenchikov (2009). Benefits, Risks, and costs of stratospheric geoengineering, Geophysical Research Letters, 36, D19703, doi:10.1029/2009GL039209

6. Mitchell, D. L.; Finnegan, W. (2009). "Modification of cirrus clouds to reduce global warming". Environmental Research Letters 4 (4): 045102.Bibcode:2009ERL.....4d5102M. doi:10.1088/1748-9326/4/4/045102.

7. Kepler-47: A Transiting Circumbinary Multi-Planet System, Jerome A. Orosz, et al. arXiv:1208.5489 [astro-ph.SR]

8. Extreme Climate Variations from Milankovitch-like Eccentricity Oscillations in Extrasolar Planetary Systems, David S. Spiegel arXiv:1010.2197 [astro-ph.EP]

9. Exoplanet albedo spectra and colors as a function of planet phase, separation, and metallicity Kerri L. Cahoy, Mark S. Marley, Jonathan J. Fortney arXiv:1009.3071 [astro-ph.EP]

10. Kreidberg, Laura et al. (January 1, 2014). "Clouds in the atmosphere of the super-Earth exoplanet GJ 1214b". Nature (journal) 505: 69–72. doi:10.1038/nature12888.

11. Bailey, J., (2007) Rainbows, Polarization, and the Search for Habitable Planets. Astrobiology. April 2007, 7(2): 320-332. doi:10.1089/ast.2006.0039.

12. Detecting industrial pollution in the atmospheres of earth-like exoplanets. Henry W. Lin, et al. arXiv:1406.3025 [astro-ph.EP]

13. Knicole D. Colon , et al. Probing potassium in the atmosphere of HD 80606b with tunable filter transit spectrophotometry from the Gran Telescopio Canarias. arXiv:1008.4800 [astro-ph.EP]

14. Polarized reflected light from the exoplanet HD189733b: First multicolor observations and confirmation of detection S. V. Berdyugina, A. V. Berdyugin, D. M. Fluri, V. Piirola arXiv:1101.0059v1 [astro-ph.EP]