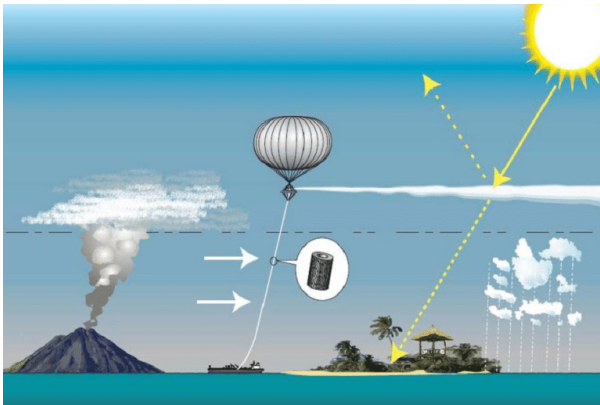


Geoengineering in South Africa

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In the wake of the 2015 Paris Agreement adopting “well below 2°C” as the international goal to limit global warming, geoengineering is increasingly being promoted as a technological means to counteract climate change or its effects. This article unpacks the state of play of these technologies in South Africa.

by Neil Overy

Geoengineering, sometimes called climate engineering, refers to deliberate attempts to intervene in earth systems to try and influence the impacts of climate change. These interventions fall into two broad categories – carbon dioxide removal (CDR), and solar radiation management (SRM). Theoretically speaking, CDR technology attempts to remove CO₂ from the atmosphere, whereas SRM technology attempts to cool the earth by reflecting a portion of incoming sunlight/solar radiation back to space.

Interventions can take place in the ocean, on land and in the earth’s atmosphere. Geoengineering represents a potential technical fix, and does not in any way attempt to deal with the root causes of climate change. Rather, it is an attempt to limit, or slow down, some of the impacts of climate change. While most of the proposed interventions are largely theoretical, some small projects have been initiated in different parts of the world.

The fact that geoengineering attempts to manipulate earth systems means that it presents unique challenges in terms of its management and regulation. For example, while geoengineering could be banned in Botswana, experiments in South Africa would inevitably effect Botswana. This argument can be extended worldwide because there is no clear scientific understanding of the impact that geoengineering technologies will have, both geographically and temporally. Therefore, an experiment in the Global North could have an impact thousands of kilometres away in the Global South. In addition, many geoengineering interventions, especially those relating to SRM, cannot be stopped once they are started (the so-called ‘termination shock’), obviously increasing the danger of interventions that have unintended consequences.

South Africa’s involvement with geoengineering has to date focussed on ocean fertilisation (OF). However, more recently, pressure has mounted for South Africa to explore SRM. A number of other technologies, considered by some to be types of geoengineering, such as carbon capture and storage (CCS) and afforestation, have been initiated or are being attempted in South Africa.

Ocean Fertilisation

There are two basic types of marine geoengineering: those that involve depositing materials or other matter into the ocean, and those that involve the construction of structures either under the ocean or floating on it. OF refers to the former category and is a form of CDR technology where iron filings are dumped into oceans to stimulate the production of phytoplankton which will absorb CO₂, and hopefully deposit it on the ocean floor when it dies.

South Africa's experience of OF has been mixed. Controversy erupted in 2009 when a ship left Cape Town at the start of the so-called LOHAFEX expedition which was co-sponsored by India and Germany. The ship dumped six tonnes of iron sulphate over an area of 300 square kilometres in the Southern Ocean, but the experiment was ended early by the German government after concerns grew over the likely environmental impact of doing so.

While the LOHAFEX expedition had no South African representation, and no similar experiments have taken place directly into the Southern Ocean since 2009, South African researchers have worked, and continue to work, on the issue of iron in the Southern Ocean. The Southern Ocean Carbon & Climate Observatory (SOCCO) at the government funded Council for Scientific and Industrial Research (CSIR), and associated academics from universities in South Africa, have spent a number of years exploring, among other things, how iron impacts the Southern Ocean's biology and its relationship to climate and CO₂. Specifically, they have assessed if it is possible to enhance the ocean's natural ability to take up CO₂. It is important to note that this research has not involved any direct dumping of iron into the Southern Ocean, as experiments have been entirely lab or ship-based. For example, researchers from the universities of Cape Town, Stellenbosch and the CSIR have undertaken a number of iron fertilisation experiments on-board the South African government's research ships, the MV SA Agulhas I and II, in different parts of the Southern Ocean in recent years. These experiments, undertaken during annual trips into the Southern Ocean, have examined both natural and artificial processes of iron fertilisation.

Scientists involved in the work have recently stressed grave doubts as to the efficacy of iron fertilisation and have adopted a strict precautionary approach to their work.^[1] As Dr Fietz, from the Department of Earth Sciences at the University of Stellenbosch recently stated 'in terms of geo-engineering for climate mitigation, it is an easy answer by now: it is not an option, people should not rely on it for climate mitigation.'^[2] Despite this, it is clear that there is still some hope among South African scientists that artificial iron fertilisation may be able to contribute to CDR at some point in the future.

Solar Radiation Management

SRM technology seeks to compensate for the atmospheric heating associated with climate change by injecting tiny particles into the atmosphere to reflect the heat of the sun and prevent it from becoming trapped in the earth's atmosphere.

In November 2012 the international Solar Radiation Management Governance Institute (SRMGI), in partnership with the African Academy of Science (AAS), held the second on three African workshops on SRM in Johannesburg.^[3] At this meeting, attended by a small number of representatives from the region, participants were encouraged to share their views on SRM. According to SRMGI:

participants expressed that it is important for Africa to be actively involved in deliberations on geoengineering, to enhance capacity of its research centres and associated scientists, and to make contributions to the development of technologies like SRM.^[4]

While no specific recommendations came out of this, or the other two SRMGI meetings, it is clear that the idea of SRM in Africa is starting to be debated. This was confirmed in January 2016, when Prof. Mike Muller from the University of the Witwatersrand authored a popular piece on SRM. This piece, 'A sunshade to help southern Africa cope with climate change?', argues that unless Africa adopts geoengineering options it will be 'left behind by other countries'. He draws specific attention to SRM stating, 'doing this to mitigate climate change needs to become a research priority'. He contends that research needs to focus on the regional SRM which could help address droughts and encourage crops and livestock production. He even goes as far as to suggest that South African Airways could be used as a means by which to disperse sulphur dioxide.^[5] Despite these claims, there is no SRM research being undertaken in South Africa.^[6]

Other Geoengineering Technologies?

When considering the situation in South Africa, it is important to acknowledge that there are a number of other initiatives that are taking place in the country which can arguably be considered geoengineering technologies or, in the case of cloud seeding, have similarities to geoengineering.

Carbon Capture and Storage

While the United Nations Convention of Biodiversity (see below) does not consider CCS a form of geoengineering,

this is not a view that is shared by all. For example, some argue that it is geoengineering because it is 'an attempt to counter the climate change threat by means of an engineering technique rather than engaging with the root causes'.^[7]

CCS refers to a process whereby CO₂ emissions are captured at source, turned into liquid form and then stored underground to theoretically ensure that they are not released into the atmosphere. In 2009 the state-owned entity, the South African National Development Energy Institute (SANEDI), created the South African Centre for Carbon Capture and Storage (SACCCS). Funded by the South African government, the World Bank, the European Union, Eskom and private companies such as AngloAmerican, SACCCS is mandated to explore CCS in South Africa.

While the use of CCS in South Africa has been promoted by the South African government as a climate change mitigation 'Flagship Programme', progress towards the application of the technology in South Africa appears to be stalling.^[8] By 2017 a R1 billion pilot CCS project was supposed to be up and running, but by the beginning of 2018 the site for such a project had not even been selected.^[9] The intended completion date for this project has been put back until 2021.^[10] In late 2018, a report commissioned by SANEDI stated that:

South Africa will decarbonise its economy and reduce its greenhouse gas emissions intensity predominantly through avoidance, by shifting to less emissions intensive and non-carbon-based power generation, notably renewable, natural gas and nuclear power.^[11]

This finding seems to go a long way towards undermining the whole CCS undertaking. South Africa has already begun to transition away from fossil fuels towards renewable energy sources, thus questioning the need for expensive investments to be made in CCS at all. It may well be that the South African government sees the realisation of its CCS project as a means by which to prevent recently built coal-fired power stations (Medupi and Kusile) becoming stranded assets. In this sense CCS could be seen as a means by which to extend the life of polluting coal-fired power stations, making CCS a regressive technological programme.

Cloud Seeding

Cloud seeding is a localised form of weather modification where substances are dispersed into pre-existing clouds in an attempt to increase the amount of precipitation that falls from the clouds that are 'seeded'. While cloud seeding is generally not considered a form of geoengineering, and is much more localised in scope and takes place at much lower altitudes than SRM, it does share some similarities with it. For example, some SRM techniques such as Marine Cloud Brightening and the proposal to try and increase cloud cover, involve spraying substances, often salt particles, into clouds. Lessons from South Africa's experience with cloud seeding should be heeded in any consideration of geoengineering.

Research in South Africa into cloud seeding, or rainfall enhancement as it was called in South Africa, began as early as 1970, but it was not until the start of the South African Rainfall Enhancement Programme (SAREP) in 1997 that it received significant funding. Supported financially at various times by the national departments of Agriculture; Water Affairs and Forestry; and Arts, Culture, Science and Technology, as well as the provincial government of Limpopo and the South African Weather Service, SAREP ran for four years.^[12] It was based in a 100 square kilometre area within the Limpopo province, an area in the north of the country which was experiencing a drought. Between 1997 and 2001, 127 storms were monitored, of which 62 were seeded. Researchers state that 24% more rain fell during seeding operations than would have fallen if seeding had not taken place, claiming that seeding 'holds considerable promise as a viable technology for integrated water resource management'.^[13] It should be pointed out, however, that this claim is disputed by other scientists who have worked in the field.^[14]

Despite this observation, funding for the project ended in 2001 as budgets were redirected towards making better use of available water resources.^[15] In recent years, however, interest in rainfall enhancement has re-emerged due to the ongoing drought in the west of the country. A number of news reports and radio shows have drawn attention to rainfall enhancement as a potential solution.^[16] In February 2018 a private South African company, Water Analytical Services, announced that it was ready to begin cloud seeding in South Africa if asked to do so. Its managing director, Franco van der Merwe, stated 'investment in cloud seeding technology has clear benefits for the private and public sectors in South Africa ... why not explore its ability to bring rain to those who need it most?'^[17] It is clear that as the negative impacts of climate change are felt more frequently, calls for the renewal of activities such as cloud seeding are likely to increase.

There are, of course, risks associated with cloud seeding. The successful implementation of the programme could

lead to the problem of rainfall dependency, rather than the creation of more resilient and efficient farming and living practises. In addition, research has shown that cloud seeding can lead to damaging sudden temperature drops.[18] Of particular concern in South Africa, is the potential link between cloud seeding and the burning of fossil fuels. One of the alleged 'benefits' of the cloud seeding that took place between 1997 and 2001 was the additional water that could be provided to cool power stations.[19] Given that South African produces 77% of its electricity from coal-fired power stations, this additional water has the potential to further entrench the burning of coal. We are therefore presented with a vicious cycle, whereby cloud seeding provides water to areas impacted by climate change-induced drought, but at the same time produces water for coal-fired power stations which are partly responsible for the climate change-induced drought.

Aside from lessons relating to how aerosol injection impacts of atmospheric conditions, perhaps the key lesson that can be learnt from the SAREP relates to the important role that government regulations can and must play when it comes to geoengineering. Rainfall enhancement is described as a 'controlled activity' in South Africa in terms of the National Water Act of 1998, including its various amendments. This Act states that any activity 'aimed at the modification of atmospheric precipitation' can only take place if an Environmental Impact Assessment has taken place and the approval of the Minister of Environmental Affairs has been gained.[20] This regulatory regime has ensured that cloud seeding activities have been tightly controlled and monitored in the wider interests of South Africa. Describing the situation before this regulatory regime, Bob Scholes, Professor of System Ecology at the University of the Witwatersrand, indicated that it was like the 'wild west' and was 'a complete mess' because the seeding of clouds was not officially controlled which resulted in consternation from within farming communities.[21]

Afforestation

The mass planting of trees and/or plants due to their carbon sequestration potential has been described by some as a form of geoengineering, while others have asserted that it 'falls rather awkwardly into geoengineering because if you did them at a large enough scale you could have a carbon dioxide reduction effect'.[22] In 2004, a DEA and Development Bank of South Africa test project, the Subtropical Thicket Restoration Project (STRP), was launched in South Africa to grow an indigenous plant called Spekboom which is highly efficient at absorbing carbon dioxide. While the project, located in the Eastern Cape province of South Africa, was partly designed to help restore degraded thicket, it was very much considered a carbon sequestration project which was designed to create sellable carbon credits. While the global economic downturn from 2008, and the failure of the South African government to timeously roll out its carbon tax, have negatively affected this project, by the end of 2011 some 2600 hectares of spekboom had been planted.[23] Given that South Africa is set to introduce its carbon tax in 2019, there may well be renewed interest in spekboom plantations. The private company Africarbon certainly thinks so, arguing that over one million hectares of degraded thicket 'represents a significant business opportunity for spekboom carbon farmers'.[24]

Prof Scholes, who has specific research interests in this area, expressed his doubts about the potential of afforestation as a means by which to address climate change. He notes that its potential in South Africa is seriously constrained because South Africa is a water scare country and because research demonstrates that any net gains are cancelled out by the changes in the reflectivity of the land surface caused by afforestation.[25]

The South African Government's Position on Geoengineering

On a global scale South Africa is a signatory to a number of conventions that relate to geoengineering. In terms of climate change, South Africa is a member of the Intergovernmental Panel on Climate Change (IPCC). Since 2013 the IPCC has been debating the use of some geoengineering technologies as possible mitigation strategies. At last year's meeting of the IPCC, geoengineering was made one of eight cross-cutting issues to be considered by each of the IPCC's three Working Groups (on the physical science side of climate change/impacts (WGI), on adaptation (WGII), and on mitigation/response measures (WGIII)) which feed into the IPCC's 6th Assessment Report (set to be published in 2021). In addition, geoengineering has been negotiated specifically into the outlines of both WGI and WGIII. What all this means is that geoengineering is, despite growing concerns about its use, featuring far more prominently in IPCC considerations than it previously has and is given undue prominence vis-à-vis other response measures.[26]

South Africa is also a member of the United Nations Framework Convention on Climate Change (UNFCCC). The government has reported to the UNFCCC that its CCS project is a key climate mitigation strategy.[27] South Africa is also a signatory of the United National Convention of Biological Diversity which imposed a moratorium on any

geoengineering that may 'affect biodiversity'.^[28] In addition, South Africa is a signatory to the Prevention of Marine Pollution by Dumping of Wasters and Other Matter (1972) – popularly known as the London Protocol.^[29] In October 2013 an amendment was made to the London Protocol which prohibits OF except for legitimate research as defined by the protocol.^[30] South Africa is yet to ratify this amendment.

In terms of the national regulatory environment, there are no regulations which specifically relate to geoengineering. There is, however, a single piece of pending legislation that makes reference to geoengineering. In 2014 the South African Department of Environmental Affairs (DEA) produced a White Paper called the National Environmental Management of the Ocean. This White Paper notes that the DEA will define a regulatory regime for any new human activity in the ocean. It states that:

international trends suggest that proposed new activities are likely to include carbon sequestration and storage, ocean fertilisation, geo-engineering and deep sea exploration.^[31]

As the White Paper has yet to even become a Bill, let alone an Act, no such regulations currently exist in South Africa.

Dr Pedro Monteiro, Chief Oceanographer at SOCCO, recently noted, 'the policy space is not clear at all' illustrating just how unprepared South Africa appears to be if geoengineering is to proceed in any substantive way.^[32] At present, if any geoengineering projects were proposed and initiated they would be undertaken under current regulations such as the National Environmental Management Act, the National Environmental Management: Waste Act, the National Environmental Management: Air Quality Act and the Marine Pollution (Prevention of Pollution from Ships) Act. None of this legislation has geoengineering in mind and therefore there are no specific regulations governing its use.^[33] This is clearly an area where efforts need to be made to ensure that legislative and regulatory provisions keep up with developments in geoengineering.

Geoengineering, Civil Society and the Media

There is very little public debate about geoengineering in South Africa. This is largely because it has not featured as a particular issue in the advocacy campaigns of environmental NGOs based in South Africa. A quick review of the websites of seven main environmental NGOs in South Africa, indicated that only one draw limited attention to it in regard to South Africa.^[34] The explanation for this absence can be found in the huge range of pressing environmental issues that face the country, and in the absence of any government proclamations or public intentions to undertake geoengineering in South Africa outside of the CCS project.

This absence is also reflected in the South African media, which appears to have had, and continues to have, very little interest in geoengineering.

The Way Ahead

In April 2018 an opinion piece, signed by 12 authors, nine of whom are from the Global South, appeared in Nature Magazine which argued that 'developing countries' must lead on SRM research. This group of authors, who are closely associated with the SRMGI, argue that unless countries of the Global South undertake research into SRM 'voices from the Global North will set the policy agenda and decide which research projects should be accelerated or shut down'.^[35]

Scientists and analysts in South Africa have voiced similar concerns. Professor Harald Winkler from the Energy Research Centre at the University of Cape Town recently stated that more research does need to be undertaken into geoengineering 'precisely because of possibly large risks'.^[36] This sentiment is echoed by Dr Monteiro who argues that research is desperately needed in South Africa to enable African scientists to be able to properly evaluate and assess the risks of what is being proposed. He states that 'strengthening South Africa's position from a science and policy perspective around geoengineering is a very high priority'.^[37] A similar conclusion is made by Prof. Scholes who argues that while he is 'deeply sceptical' about geoengineering it is 'valid to do research on it to establish its limits and its viability'.^[38]

This is clearly a compelling argument. At present geoengineering is being driven by the Global North, and South Africans, and others living in the Global South more generally, need to be able to assess the risks and implications of this work. This assessment indicates that more research from the Global South is necessary to enable the informed rejection of geoengineering. Such research should not, however, involve experimentation in

geoengineering itself, the risks are simply too great.

[1] Author interview with Dr Pedro Monteiro, Chief Oceanographer, Southern Ocean Carbon & Climate Observatory, Council for Scientific and Industrial Research, Cape Town, 4 May 2018.

[2] Email correspondence with Dr Susanne Fietz, 24 April, 2018. See also, F. Preston-Whyte, 'Why Iron Can't Solve the Climate Crisis', 10 April 2015, www.socco.org.za/news/why-iron-cant-solve-the-climate-crisis/. Accessed 14 May 2018.

[3] The SRMGI describes itself as 'an international, NGO-driven project that seeks to expand the global conversation around the governance of SRM geoengineering research', <http://www.srmgi.org/>. Accessed 2 May 2018.

[4] 'Solar Geoengineering: Research, Governance, and African Involvement', *SRMGI*, 28 Nov. 2012. <http://www.srmgi.org/events/solar-geoengineering-research-governance-and-african-involvement/>. Accessed 3 May 2018.

[5] M. Muller, 'A sunshade to help southern Africa cope with climate change?', *The Conversation*, 22 Jan. 2016, <https://theconversation.com/a-sunshade-to-help-southern-africa-cope-with-climate-change-53452>. Accessed 4 May 2018.

[6] Author telephone interview with Prof. Bob Scholes, Professor of Systems Ecology, University of the Witwatersrand, 15 May 2018.

[7] 'CCS as a Geoengineering Practise', *CCS-Info*, Friends of the Earth Denmark. <http://ccs-info.org/CCS%20as%20geoengineering.html>. Accessed 14 May 2018. See also, 'The Big Bad Fix: The Case Against Geoengineering', Heinrich Boll Foundation, 2017, p. 14. Prof. Scholes considers CCS a form of geoengineering, author telephone interview with Prof. Bob Scholes, Professor of Systems Ecology, University of the Witwatersrand, 15 May 2018.

[8] 'South Africa's Second Annual Climate Change Report: 2016', Department of Environmental Affairs, Nov. 2017, p. 54.

[9] 'The South African Centre for Carbon Capture & Storage', SANEDI, Fact Sheet 1, no date.

[10] B. Beck, N. Kulichenko-Lotz, T. Surridge, 'World Bank CCS Programme Activities in South Africa - Results and Lessons Learned', *Energy Procedia*, 114, 2017, p. 5637 & 'Prospectus: Addressing Climate Change Through CCS Technology: The South African Centre for Carbon Capture and Storage Programme', SACCS & SANEDI, 21 Feb. 2018, p. 13.

[11] 'Analysis of CO₂ Utilisation Technologies and Their Suitability for Implementation in South Africa', SANEDI, Feb. 2018, p. 102.

[12] D. Terblanche, M. Mittermaier, R. Burger, K. de Waal, X. Ncipha, 'The South African Rainfall Enhancement Programme: 1997 - 2001', *Water SA*, 31(3), p. 292.

[13] D. Terblanche, 'The South African Experience in Rainfall Enhancement Research in a Global Context', *The World Meteorological Organisation's Role in Weather Modification Research*, no date, pp. 2 - 3. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.516.3598&rep=rep1&type=pdf>. Accessed 3 May

2018.

[14] Author telephone interview with Prof. Bob Scholes, Professor of Systems Ecology, University of the Witwatersrand, 15 May 2018.

[15] J. Davenport, 'SA's Rain-making System May Soon be Back on Track', *Engineering News*, 2 Oct. 2006, <http://www.engineeringnews.co.za/print-version/sas-rainmaking-system-may-soon-be-back-on-track-2006-10-02>. Accessed 2 May 2018.

[16] See, for example, T. Taylor, 'Is Cloud Seeding the Answer for the Rain in South Africa', *ENCA*, 19 Nov. 2015, <https://www.enca.com/technology/cloud-seeding-answer-rain-south-africa> & 'Is Cloud Seeding Viable for South Africa', *Cape Talk*, 8 Jan. 2016, <http://www.capetalk.co.za/articles/10708/is-cloud-seeding-viable-for-south-africa>. Accessed 2 May 2018.

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[20] Section 37(1)b of the National Water Act (1998) and K. Shippey, A. Gorgens, D. Terblanche, M. Luger, 'Environmental Challenges to Operationalisation of South African Rainfall Enhancement', *Water SA*, 30 (5), p. 89.

[21] Author telephone interview with Prof. Bob Scholes, Professor of Systems Ecology, University of the Witwatersrand, 15 May 2018. Prof. Scholes Bob was an author of the Intergovernmental Panel on Climate Change 3rd, 4th and 5th assessments and has undertaken risk assessment research on geoengineering. See, C. McCormack (et al), 'Key Impacts of Climate Engineering on Biodiversity and Ecosystems, with Priorities for Future Research', *Journal of Integrative Environmental Sciences*, Vol. 13, pp. 103 - 128.

[22] 'The Big Bad Fix: The Case Against Geoengineering', Heinrich Boll Foundation, 2017, p. 15. See also, 'New report highlights risks of large-scale biosequestration as a form of CO2 removal', *Geoengineering Monitor*, 11 Oct. 2017, <https://www.geoengineeringmonitor.org/2017/10/new-report-highlights-risks-of-large-scale-biosequestration-as-a-form-of-co2-removal/>. Accessed 15 May 2018 and author telephone interview with Prof. Bob Scholes, Professor of Systems Ecology, University of the Witwatersrand, 15 May 2018.

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[24] <http://www.africarbon.co.za/Concept.html>. Accessed 15 May 2018.

[25] Author telephone interview with Prof. Bob Scholes, Professor of Systems Ecology, University of the Witwatersrand, 15 May 2018.

[26] 'Geoengineering Further Encroaching on the IPCC's Work: 46th IPCC Meeting in Montreal, Canada', *Geoengineering Monitor*, 20 Sept. 2017. <https://www.geoengineeringmonitor.org/2017/09/geoengineering-further-encroaching-on-the-ipccs-work-46th-ipcc-meeting-in-montreal-canada/>. Accessed 7 May, 2018.

[27] 'South Africa's 2nd Biennial Update Report', Department of Environmental Affairs, Oct. 2017, p. 136. https://www.unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/application/pdf/south_africa_2nd_bur.pdf. Accessed 7 May 2018.

[28] 'The Big Bad Fix: The Case Against Geoengineering', Heinrich Boll Foundation, 2017, p. 55.

[29] 'The Big Bad Fix: The Case Against Geoengineering', Heinrich Boll Foundation, 2017, p. 58.

[30] See, https://www.gc.noaa.gov/documents/resolution_lp_48.pdf. Accessed 14 May 2018.

[31] Policy State 3.2.2, White Paper on the National Environmental Management of the Ocean, 29 May 2014. https://www.environment.gov.za/sites/default/files/legislations/nemo_whitepaper_no37692_gn426.pdf. Accessed 14 May 2018.

[32] Author interview with Dr Pedro Monteiro, Chief Oceanographer, Southern Ocean Carbon & Climate Observatory, Council for Scientific and Industrial Research, Cape Town, 4 May 2018.

[33] See, for example, 'Review of South African environmental regulatory requirements relevant to injection and storage of CO₂ for the Test Injection Project, South Africa-EU Cooperation on Carbon Capture and Storage (SAfECCS), 2012.

[34] Only GroundWork mentioned geoengineering. Greenpeace Africa, WWF South Africa, Earth Life Africa, South African Faiths Environmental Institute, Project 90 by 2030 and 350.org make no reference to it on their respective websites. This does not mean, however, that they have no official positions on the matter.

[35] A. Atiq Rahman, Paulo Artaxo, Asfawossen Asrat & Andy Parker, 'Developing Countries Must Lead on Solar Geoengineering Research', *Nature*, 3 April, 2018. <https://www.nature.com/articles/d41586-018-03917-8>. Accessed, 5 May 2018.

[36] Email correspondence with Prof. Harald Winkler, 26 April, 2018.

[37] Author interview with Dr Pedro Monteiro, Chief Oceanographer, Southern Ocean Carbon & Climate Observatory, Council for Scientific and Industrial Research, Cape Town, 4 May 2018.

[38] Author telephone interview with Prof. Bob Scholes, Professor of Systems Ecology, University of the Witwatersrand, 15 May 2018.