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***Antarctica and Climate Change***

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**Abstract/Executive Summary:**

The concept of climate change and the ability of mankind to alter natural cycles of global temperature, over a relatively short timescale is something that has never before been encountered on this planet. The evidence for such change arises from a variety of sources, however the most convincing argument related to the validity of this effect originates from the ice core samples of Antarctica. Gas bubbles entrained in compressed snow over thousands of years provide a snapshot of the atmospheric conditions present during these times. The concentrations of trace gases such as CO<sub>2</sub>, as well as the stable isotopic ratios of elements such as oxygen can be used to determine historic temperature variations as well as predict future temperature rises. The main uncertainty with this simplified model is not if temperatures will rise with elevated CO<sub>2</sub> but when, how fast will this process occur and what impacts this will have on the flora and fauna of the world.

In attempting to answer some of these questions one must look at areas of the planet where climate change is currently having the most visible and significant impacts. The West Antarctic Peninsula is currently one of the fastest warming areas on Earth and is experiencing significant and measurable change to its climate and the species that inhabit this region. How this information is communicated and portrayed to the world's populations is therefore crucial to their understanding of climate change, its implications and effects, as well as preventative actions that can be undertaken both by the individual and as a country.

## *Introduction*

Antarctica is an unmatched wilderness vital for scientific research that is important in a local and global context and virtually impossible to replicate elsewhere on the planet. Furthermore, some of the most convincing arguments involving climate change have arisen from research conducted in this region, with studies using ice core data, as well as atmospheric sampling, providing robust arguments regarding potential future long term effects on global climate change (SCAR 2016a).

Antarctica is however a large continent and as such, climate change effects are not uniform throughout and comprises two geologically different areas, East Antarctica and West Antarctica, which are separated by the Trans-Antarctic Mountains. These are also joined together by an ice sheet that encompasses the whole continent. The annual sea ice cover around the continent can extend to an area greater than that of Antarctica itself. It also controls exchanges of heat, atmospheric trace gases such as CO<sub>2</sub> and moisture, between the atmosphere and ocean through processes such as the rejection of salt from the freezing of water and the direction of cold oceanic bottom waters away from the continent thus keeping the world's oceans cool (ASOC 2016).

As well as sea level rise there are also numerous other important messages arising from climatological studies of Antarctica. Marine species such as Krill often feed on algae underneath sea ice and populations have been in steady decline in the West Antarctic Peninsula as the sea ice in this area has shown a marked decrease in recent times (SCAR 2016b). As a major food source for numerous other species in the southern ocean, both resident and migratory, reduction in Krill numbers may have a profound effect on the populations of other organisms including those of fish stock species commercially harvested in the Southern Ocean (Everson 2000). Other species including the Adélie penguin populations have been also been in decline in recent years due to reductions in krill populations and changing weather conditions in their traditional nesting areas. Many marine species have also adapted to survive in a very specific temperature range, with studies showing that these 'stenothermic organisms' are unable to adapt to some of the predicted increases in temperatures for the Southern Ocean. Potential Ocean acidification, from increased dissolved atmospheric CO<sub>2</sub>, is also predicted to impact on marine invertebrates such as molluscs and their associated food webs (Hempel 1985).

Due to the importance and complexity of research in Antarctica the Scientific Committee on Antarctic Research (SCAR) was formed in 1958. The SCAR organisation is charged with initiating, developing and coordinating high quality international scientific research in the Antarctic region (including the Southern Ocean), and on the role of the Antarctic region in the Earth's climate system (SCAR 2016a). Such research continues to yield many ground-breaking discoveries and is relevant to numerous other aspects of science. Due to the remoteness of this continent however, the climate and species that inhabit this region of the world are not always at the forefront of current western thinking. The methods used to communicate the science around climate change, which have been derived from this area, therefore require significant thought and effort, which must be put into a context that is both clear and relevant to the target audience. This study will therefore examine the key messages that have been derived from science conducted in this region, as well as the how these messages are portrayed in the media. Information will also be garnered regarding material that may be conveyed more effectively to the general public and policy makers, as well as the potential political impacts of Antarctic climate change research.

## *Climate and Sea Level Rise*

Antarctica has been the focus for ground-breaking climate research for a number of years, including the discovery of the Ozone Hole in 1985, as well as the influence the Polar Vortex has on the world's weather systems and the study of past climates using the Vostok ice core samples (Florindo 2008). Currently this science has never been more important with the continent's meteorology being pivotal in determining potential changes in sea level, should processes occur to allow this ice to melt. With the majority of the world's major urban centres located in predominantly low lying areas, this therefore has huge immediate implications for these regions and the populations within them.

Antarctica contains a large proportion of the world's fresh water, which is currently frozen in an ice sheet up to 4 km thick. The thick ice sheet reflects incoming solar radiation and in the ocean, saltier water forms around sea ice as these salts drain out of freezing sea water. This high saline solution then sinks due to its greater density, forming cold 'oceanic bottom waters' that spread out under the world's oceans (NSIDC 2016). It has also been argued that the apparent increase in sea ice observed since 2007 in Antarctica is cause to dispel claims about the effects of global warming in the southern continent (Vinnikov *et al.* 2006).

It is believed however, that there are several contributing factors causing an increase in current sea ice levels, which is predicted in a world that is globally warming. It is thought that the partial absence of Ozone, which is believed to be a significant greenhouse gas, at locations such as the South Pole, has caused cooling in the stratosphere (Gillett 2003). In addition, a potential side-effect of the Ozone hole is the strengthening of the cyclonic winds that circle the Antarctic continent. These winds push sea ice around, creating areas of open water where new sea ice can form (Thompson 2002). Another current hypothesis regarding this apparent anomaly in the climate model involves changes in Southern Ocean's circulation patterns. This body of water consists of a cold layer near the surface and a layer of warmer water below, with warmer water rising to the surface and melting the sea ice. As air temperatures warm however, the quantity of snowfall also increases, which freshens the top water layers, leading to surface water that is less dense than the saltier, warmer water below (Zhang 2007). Mixing is subsequently reduced and less heat is transported upwards from the deeper, warmer layer, which consequently lessens the amount of sea ice that is melted. Although sea ice is apparently increasing overall in Antarctica the methods used to measure this coverage generally don't account for thickness so although more visible sea ice may be present on the surface this may be relatively thin with the overall mass of sea ice still decreasing.

The Antarctic ice sheet as a whole contains enough ice to elevate global sea level by over 60 meters if melted in its entirety. It is however thought that only a relatively small portion of this will melt in the near future with the majority of the East Antarctic ice sheet remaining intact, primarily due to its elevation above sea level and overall significantly lower average temperatures. Melting of the West Antarctic ice sheet, as well as retreat and outflow from several large East Antarctic glaciers is however a very real possibility in the next 50-100 years, with levels estimated to produce a rise of between 1 and 3 m above the current global sea level in this timeframe.

As the West Antarctic ice sheet is predominantly below sea level these low lying conditions allow relatively warmer sea water to permeate deep into the continent's structure and the specific geology of smooth sandy/silty bedrock allows rapid movement of ice flows over its surface and out towards the open ocean. Such conditions make it highly susceptible to rapid shrinkage. In the Eastern Antarctic ice sheet however, the much higher average elevation with a geology predominantly consisting of rough volcanic rock provides significantly more resistance to ice movement than the silty material of Western Antarctica (Zhang 2007).

In addition, due to the relatively low average elevation of West Antarctic Ice Sheet the area is not as well protected from cyclones as the Eastern portion. These cyclones circle the continent and transport warm, moist air from lower latitudes into this region. In addition, many current climate models predict these cyclones to become more frequent and intense, with the Western Antarctic Ice Sheet may become much warmer as a result (IPCC 2007).

In summer, temperatures in the north-east Peninsula can warm by up to 5°C, creating the conditions that favoured drainage of meltwater into crevasses on the Larsen Ice Shelf. This was a key process which led in 2002 to its break-up. Climate records from the west coast of the Antarctic Peninsula indicate that temperatures have risen by over 3°C during the past 60 years for this region, equating to an approximate 10 fold increase based on the global average (BAS 2016).

As described earlier global temperatures can be directly linked to atmospheric CO<sub>2</sub> concentrations. Direct and continuous measurements of this greenhouse gas in our atmosphere extend back only as far back as the 1950s. Ice core measurements however, allow scientists to significantly extend this period by thousands of years. In addition, sites such as Law Dome in Eastern Antarctica experience very high annual snowfall rates and it has therefore been possible to measure atmospheric CO<sub>2</sub> concentrations from as recently as the 1980s using ice core extraction techniques. Subsequent comparisons with measurements made at South Pole station indicate that these samples provide an accurate and valid method to determine atmospheric concentrations of trace gases.

Antarctic ice cores indicate that CO<sub>2</sub> concentration was relatively stable over the last millennium up until the start of 19th century. From then it rose increasing to a level that is now approximately 40% higher than pre-industrial revolution concentrations. Isotopic data of gases in these ice cores has also confirmed that the observed increase has been due to emissions of CO<sub>2</sub> from fossil fuel usage and deforestation. This equates to an unprecedented rise in CO<sub>2</sub> concentration, which has not been observed on earth for over 800,000 years (BAS 2016).

One argument regarding climate change that is frequently used to discredit the science produced is that the variations observed are a result of natural cycles in the earth's climate. Furthermore, analysis of Antarctic ice cores and marine sediment records do reveal that the Antarctic ice sheet has grown and shrunk over geological history and has experienced numerous glacial cycles (each with an ice age and a warm period) (BAS 2016). Understanding this natural rhythm is therefore critical to obtaining a more complete model of the processes effecting Earth's current climate, as well as that of the future.

Current research published this year in the journal Nature has also indicated that the next ice age may have been delayed by over 50,000 years due to the current elevated greenhouse gas concentrations (Ganopolski *et al.* 2016). Under normal circumstances, the current interglacial period we live in would be at an end, with a new ice age starting. At present the earth is in the perfect position, from an astronomic perspective, to start this new ice age if a CO<sub>2</sub> concentration of 240 parts per million or less currently existed in the atmosphere today. Industrial society has however taken this concentration to well over 400ppm and this rise has been sufficient to allow the current 'warm' period to continue (Mauritsen 2012).

The climate changes described above were huge, but relatively gradual. Ice cores however, have provided us with evidence that abrupt changes can also be possible. Ice core data from the Greenland Ice sheet sampled from the last glacial period, indicates a sequence of very fast warmings, where temperature increased by more than 10°C within 40 years. Antarctica and the Southern Ocean experienced a feedback effect from this warming which appears consistent with the

hypothesis that these sudden jumps in temperature were caused by rapid changes in the transport of heat in the ocean.

It is believed that a huge ice sheet that once covered a large portion of North America rapidly broke up delivering large quantities of fresh water into the Ocean thus disrupting the established heat transport pathways. Tropical heat from equatorial Ocean regions was briefly reduced, then strengthened, causing the dramatic temperature rise observed. While this mechanism cannot occur in the same way today, the example does provide potential analogies with large Antarctic ice shelves such as those of the Ross and Filchner-Ronne ice shelves which may one day become unstable and vulnerable to collapse potentially having similar dramatic effect (Domack *et al.* 2005).

Antarctic climate studies therefore provide a window to our past, with this data telling us that the climate is capable of extraordinary changes, even within a human lifetime. These rapid switches would certainly be catastrophic to many communities around the globe and the challenge remains to better understand the processes that underpin these changes with the climate of Antarctica being a key player in this research.

Other impacts of climate change, particularly within the Southern Ocean, include the effects of ocean acidification on the Antarctic ecosystem and also how species may change in terms of population size, structure and location, causing multiple effects on the wider food chain.

#### *Ocean Acidification and Antarctic Species Change*

Since the beginning of the industrial revolution, ocean surface water average pH has decreased from 8.2 to 8.1 (~0.1 units) which is an increase in acidity of 26% (IPCC 2014). This change in pH is the direct result of ocean acidification.

In particular, the polar oceans are extremely susceptible, more so compared to all other oceans, to any sort of changes in its chemical balance such as the anthropogenic acidification due to the relatively low alkalinity and correspondingly, weak carbonate buffering system (Shadwick *et al.* 2013). Another distinctive characteristic of the polar waters which makes them more vulnerable to ocean acidification is that CO<sub>2</sub> is more soluble in these cold waters therefore factors effecting marine organisms will become more apparent at an earlier stage as compared to the oceans located at lower latitudes (Constable *et al.* 2014).

Many Antarctic species are stenotherms such as some Antarctic fish and compared to these are the eurytherms such as gold fish, capable of tolerating a wide range of temperatures. Both the specialist animals, the stenotherms, and the generalist animals, the eurytherms, have costs and benefits (Logan & Buckley 2015). Eurytherms can access a wider range of habitats, have the potential to expand their ranges, have increased prey availability and predator avoidance and also have a tolerance for unpredictable or rapidly changing environmental temperatures (Logan & Buckley 2015). However, the cost of eurythermy, is expected to be an energetic one such as the effects of temperature on metabolism and therefore these costs have to be dealt with in thermally variable habitats (Logan & Buckley 2015).

The cost of eurythermy is avoided by stenotherms as they are able to live within a narrow temperature range but this is only as long as the ocean temperature changes at a rate at which the animals can adapt to (Logan & Buckley 2015). This a current and major concern due to climate change in the marine environment, particularly in the polar waters (Logan & Buckley 2015). Many tropical species have already adapted to nearly constant warmer waters and must survive within their upper thermal limits, compared to the polar species who cannot adapt to rising sea surface temperatures (Logan & Buckley 2015).

Ocean acidification has two main implications for marine organisms in the Southern Ocean due to a decreased concentration in carbonate ions (Constable *et al.* 2014), both which are detrimental to the survival of the species through light and nutrient availability (Shadwick *et al.* 2013). Firstly, there is the potential to impact the organisms' physiology and secondly, are the problems associated with depositing carbonate for shell construction and therefore protection by all calcifying organisms (Constable *et al.* 2014).

These effects become apparent when there is an alteration of the saturation state of seawater in terms of calcium carbonate ( $\text{CaCO}_3$ ) making it more difficult to be extracted from the seawater by organisms and also dissolving the structures already constructed with  $\text{CaCO}_3$  such as skeletons (Gutt *et al.* 2015). These species include the coccolithophorids, pteropods, echinoderms and corals, all which will be severely affected from ocean acidification (Gutt *et al.* 2015).

In terms of which species will be affected, benthic systems will sustain the most damage after the tipping point is reached due the dramatic change from being within a saturated to under saturated environment located on many of the Antarctic ice shelves (Gutt *et al.* 2015). This environment represents 2.59% of the entire Antarctic sea-floor habitat (Gutt *et al.* 2015) therefore any effects observed here will also have wider implications for the surrounding ecosystem.

The Intergovernmental Panel on Climate Change fifth report states that if  $\text{CO}_2$  emissions continue on the current trajectory (RCP\* 8.5), 60% of Southern Ocean surface waters (on annual average) are expected to become corrosive to the organisms (IPCC, 2014).

Without these protective shells, these organisms will not be able to survive due to their physiology but they will also be defenceless against predators.

These organisms form the base of the Southern Ocean ecosystem and therefore without their presence, there will be detrimental consequences for all trophic levels in Antarctica. They feed on the algae which live beneath the surface of the ice edge which is also predicted to decline with the decrease in sea-ice extent (Constable *et al.* 2014).

Moving to the next trophic level is the Antarctic keystone species, the krill (5). Krill form a major part of the diets of many Antarctic species and as their numbers begin to diminish such as within the Scotia Sea where there has been a decline in krill numbers by 30% since the 1980s (Constable *et al.* 2014), another species, the salp, has begun to take its place in the food chain. Similar to krill, salps are omnivorous filter feeders that feed on small phytoplankton but instead avoid sea ice and occur typically where krill do not (Constable *et al.* 2014). However, due to the reductions in sea-ice, krill and salps have become to coexist in the west Antarctic Peninsula (Constable *et al.* 2014). The salps compared to krill do not contain as much nutrition as they are a gelatinous species therefore predators must consume larger amounts in order to obtain the same amount of energy.

It is believed that these organisms have developed such thin shells due to the fact that there are no crushing predators such as crabs (Watson *et al.* 2012). Crabs cannot survive within the Southern Ocean due to the inability to regulate magnesium-ions within their blood which can cause paralysis and death within the cold conditions (Aronson *et al.* 2014). However due to the increases in sea surface temperatures, in the Western Antarctic Peninsula at a volcano, durophagous (shell-breaking) Brachyuran crabs have been observed (Aronson *et al.* 2014). The geothermal heat energy provides a warmer environment which they can survive within and expand their ranges as the water warms from climate change (Aronson *et al.* 2014). Currently, the soft-substrate environment is dominated by epifaunal suspension-feeders with the top predators being slow-moving invertebrates of the benthic food web (Aronson *et al.* 2014). Within the ocean today, the Brachyuran crabs are described

as one of the successful invaders and with climate warming being a vector for their expansion, there is now the opportunity for these predatory decapods (Aronson *et al.* 2014) to prey on these sessile and slow moving invertebrates. Without any other of these species currently present in the ecosystem, it will be extremely easy to colonise and not be preyed upon.

Moving up the Southern Ocean food chain, are the pygoscelid penguins. Specifically the Adelie (*Pygoscelis adeliae*) and Gentoo (*Pygoscelis papua*) Penguins which are arguably, both affected by climate change (Forcada *et al.* 2006). Both species are very sensitive to climate change which restrict foraging ranges and depths due to size, morphology and adaptations (Forcada & Trathan 2009).

Adelies are located south of latitude 54°S and are restricted to the ice-free areas of Antarctica (Dantas *et al.* 2014). This is compared to the Gentoos which are restricted to areas that contain <50% ice cover with a significant correlation observed between the loss of this sea ice and increases in populations (Lynch *et al.* 2012). Both species require ice to survive, but more so the Adelies to nest within. Gentoo populations are expected to increase and move southward with observations at 7 sites located at the southernmost boundary of the breeding range displaying the fastest increase in numbers in the colonies that have newly been established in the last 20 years (Lynch *et al.* 2012).

Previously in Antarctica, during a warming event in the last glacial maximum, there was a decline in the extent and duration of the winter sea ice and also a retreat in the ice shelves has previously allowing species of penguins to expand their ranges south (Clucas *et al.* 2014). At this time, Southern Gentoo Penguins expanded more than their Northern populations much like the observations occurring within the sea ice of the Western Antarctic Peninsula (Clucas *et al.* 2014).

However, as this climate warming benefitted all penguin species, the current climate warming is arguably only benefits Gentoos, the most opportunistic and generalist species with a flexible foraging niche, reducing the impact of krill declines as a food resource (Clucas *et al.* 2014). This has previously been reported as a “reversal of fortunes” for the two previously climate change “winners” due to an increase in anthropogenic impacts exceeding warming past previous natural variations (Clucas *et al.* 2014).

The effects of climate change on the Southern Ocean and Antarctic ecosystem make climate change science clearly an extremely important and hot topic within today’s society, but there are many barriers between the science and trying communicate this information to the public in order to prevent these ongoing effects and try and mitigate the problem. One such problem is how the media portrays and communicate Antarctic climate change to the wider public.

*Media Portrayal of Antarctic Climate Science and Methods to improve its Effectiveness to Decision-Making Bodies.*

Scientific research in Antarctica plays an essential role in understanding the dynamics of the global climate. In December of 2015, the Intergovernmental Panel on Climate Change announced a commitment to restricting global warming to an increase of 1.5°C. The ensuing silence has been deafening in terms of how it is going to be achieved. While governmental bodies try to come to terms with what the decision means, the role of the general public, the biggest body of decision makers, seems to have been forgotten. Now, more than ever, the findings and knowledge of the global climate research community needs to be galvanising people into taking personal and daily action and to hold our business and political leaders accountable to creating the investment and policy changes that are required in order to protect the environment our future generations inherit.

While it is regarded that 95% of scientists (Solomon *et al.* 2007) agree that global climate change is underway, and that it is directly linked to human activities (which the IPCC effectively ratified by agreeing to the 1.5°C target), but then there is a distinct (and geographically variable) drop off in the level of general public acceptance that surveys report on, and another significant drop again in the level of general public climate change mitigating action that is taking place.

Future generations may well be justified in looking at us accusingly and asking “If you knew it was going to happen, why did you not act? How could you justify such non-action to yourselves when you knew what you were committing us to?”

There are aspects of the human biological and psychological build up that creates barrier for the current generation to take climate change mitigating action that is in align with the enormity of climatic situation that is evolving. This section of report explores these barriers and suggests whose responsibility it is to remove these barriers.

### 1. Complexity, Knowledge Gaps and “Confusion”

With only a little exposure to any science related to the climate and climate change, it becomes clear that it is a very complex, multi-disciplined issue. It also becomes clear that deeply understanding Antarctic climate research an essential prerequisite to deeply understanding the global climatic mechanism.

Properly grasping the dynamics of climate starts with having a working knowledge of chemistry, atmospheric physics and meteorology, ocean dynamics, biology, geology and glaciology, to name a few. Climate change research (particularly Antarctic climate research) is slow, logistically difficult and expensive, and with Antarctica being able to provide knowledge of previous climatic conditions, Antarctic climate research is particularly important for us to be able to understand past climatic states in order to be able to predict future scenarios.

While the vast majority of scientists now agree that global warming is occurring and it is caused by man’s activities (primarily the release of CO<sub>2</sub> into the atmosphere through the burning of fossil fuels), it has taken quite some time to reach this level of agreement.

As early as 1824 the French physicist Joseph Fourier described the greenhouse effect of Earth's atmosphere and in 1827 wrote “The establishment and progress of human societies, the action of natural forces, can notably change, and in vast regions, the state of the surface, the distribution of water and the great movements of the air. Such effects are able to make to vary, in the course of many centuries, the average degree of heat; because the analytic expressions contain coefficients relating to the state of the surface and which greatly influence the temperature.” (Wmconnolley.org.uk 2000).

In the late 1800’s, the Swedish scientist, Svante Arrhenius recognised that industrial aged coal burning may be able to cause global warming and in 1906 wrote in his book “*Världarnas utveckling*” (Worlds in the Making) that “any doubling of the percentage of carbon dioxide in the air would raise the temperature of the earth's surface by 4°; and if the carbon dioxide were increased fourfold, the temperature would rise by 8°” (Arrhenius & Borns 1908 p53) and that “we yet recognize that the slight percentage of carbonic acid in the atmosphere may by the advances of industry be changed to a noticeable degree in the course of a few centuries.” (Arrhenius & Borns 1908 p54).

A part of the scientific enquiry process requires scenarios and hypotheses to be proposed and tested, often seen to contradict each other, until the causal relationships are fully understood. While a part of scientific progress, what can look like scientific confusion or conflict is ready fuel for media, denialists or political proponents to selectively pick over in their search for

evidence that supports their position or agendas, creating a sideline distraction that, at least, bringing a wide spread awareness to the issue.

Even today, there are recognised and important acknowledged gaps in our research, not so much about that we are causing climate change, but more the sequence and rate at which global environment is responding to the man-made inputs (e.g. the West and East Antarctic ice mass balance). While there is still research and disagreement as a part of the scientific progress, there is an almost total agreement, to which a summary may look like “People, we do have a problem, and the problem is us”

## 2. Accessibility of Climatic Science

Being an analytical/left brained activity, science (and scientists) have a reputation for not being good at communicating with the general public. The existence of science communication as a professional field and the multitude of outreach programs is a testament to this. While it is arguable whose role it is to educate, in order for large scale climate change mitigation action to occur, the complexity must be framed in ways the general public can relate to.

While a deep understanding of the mechanics of climate change can be a lifetime pursuit for scientist - in order to comprehend the significance of climate change, the rest of the world needs to be provided with an explanation they have a chance of understanding. Based on personal observation, to ask a climatologist to explain how global warming works is likely an invite for a discourse in detail and complexity that may challenge even listeners of above average intelligence. However, the accessibility gap seems to have been acknowledged and is starting to be bridged. One such example is the 35 word explanation of the global warming mechanism from the website [HowGlobalWarmingWorks.org](http://HowGlobalWarmingWorks.org):

“Earth transforms sunlight’s visible light energy into infrared light energy, which leaves Earth slowly because it is absorbed by greenhouse gases. When people produce greenhouse gases, energy leaves Earth even more slowly—raising Earth’s temperature” (How Global Warming Works 2009).

Although lacking in detail, the essential message contains everything the general population needs to know, and it this type of message that science needs to provide in order for outreach to be successful in initiating education and in galvanising public action.

## 3. Who are the Decision Makers and Who Needs Education?

In the climate change scenario, there are 3 main decision making bodies...the governments, business, and the biggest and most power - the consuming, voting general public.

Governments have access to scientific advisors, however, how the governments act upon the scientific advice largely depends upon the political agenda and aspirations of the governing party. Under the democratic model, ultimately, if the governing parties does not follow the consensus of the general voting public, the governing party will eventually lose its power.

Business, in a similar way is ultimately answerable to the general public - which market sensitive companies are aware and can be seen in trend of “green aware” positioning and product development, even if it does result in tokenistic climate friendliness (such as the promotion of recycling, reduction and reuse programs proudly thrust forward by one of the bigger CO<sup>2</sup> emission producer, the air travel industry). Again, if the business gets it wrong in the eyes of the consumer, the longevity of that business becomes questionable.

Lastly, the consuming, voting general public. In the long term (and the short term, if properly motivated) they are the ultimate power holders. The general public is the focus of a later section, but for now, the masses are the key people that need to understand the implications of climate change and what it means to THEM. They hold the power that, if motivate and mobilised, can move to hold businesses and politicians accountable. It is this group that require catering to, the group that makes every day product buying decisions and voting decisions. One of the challenges is that this group is already under the pressure of surviving in a demanding and ever changing world, AND for the favour of competing parties within the previous 2 groups - who often selectively use environmental positions in order to further their interests.

In order to gauge public opinion surveys are often executed, however, finding global comparable data on public opinion regarding climate change proved difficult. In 2013, an online survey by Ipsos MORI of 32,306 across 20 countries (unfortunately excluding New Zealand) respondents were asked “To what extent do you agree or disagree? We are heading for an environmental disaster unless we change our habits quickly,” a total of 73% agreed and 76% agreed with the statement “The climate change we are currently seeing is largely the result of human activity”. While the validity of leading questions can be questioned, the survey illustrates the range of levels of concern vary from country to country (Fig 1).

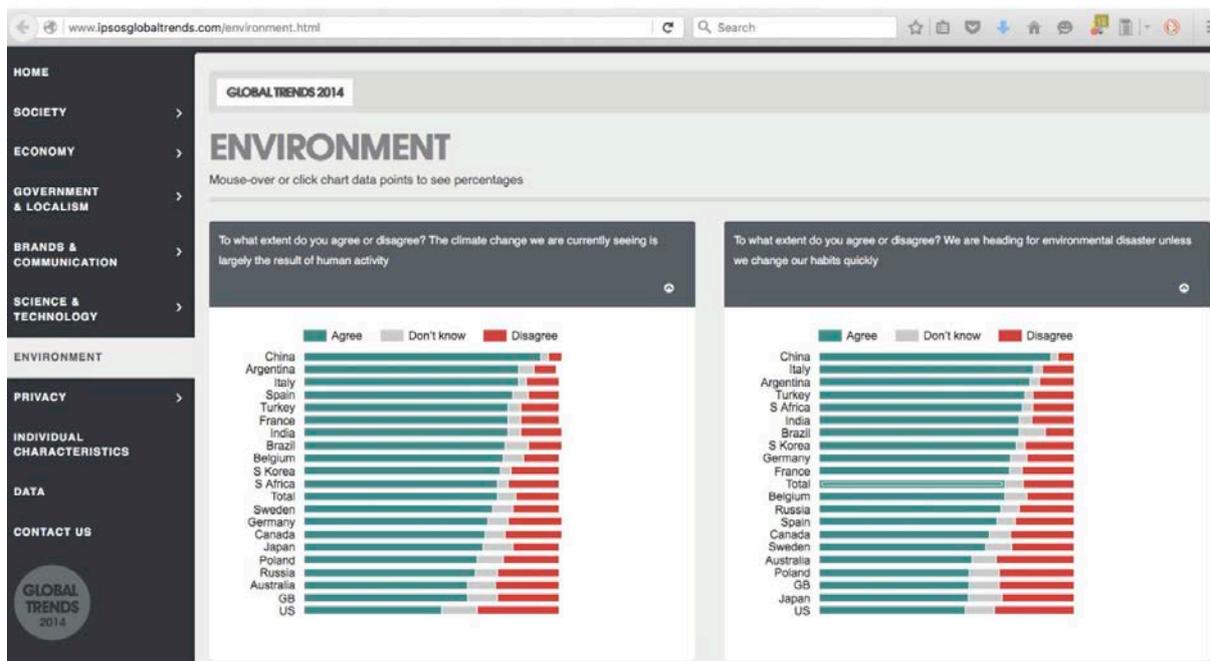


Figure 1. Ipsos MORI survey results (Ipsosglobaltrends.com 2013)

Given the severity of the consequences of continued global warming, and the level of concern shown by respondents, there seems to be a void of action in the face of such support, and at this point the human factor starts to become apparent.

#### 4. Psychological Barriers to Taking Climate Change Action

There are factors about humans, that, even given perfect information, create barriers to people taking significant levels of action, and unless these barriers are widely recognised and managed, we had better prepare for worst case scenario of climate change models, as the required higher level of action and change for better case scenarios is not going to happen.

In “Don't Even Think about It - Why Our Brains Are Wired to Ignore Climate Change”, George Marshall talks of how the right side of the brain has difficulty processing the logical/analytical style that understanding climate change requires (Marshall 2014). He uses this example to illustrate how

our minds departmentalise different aspects of our lives based on the processing style they require (Marshall 2014). Very often the contents of each 'box' do not get integrated with other aspects of our lives because it doesn't SEEM to relate, so we may not rationally act on perfect and valid information because it simply does not connect to the emotional processes required for us to act (Marshall 2014). An example can be seen in morbidly obese individuals, struggle to succeed in changing the eating and exercise patterns that are killing them.

Marshall describes 'socially constructed silence' as talking about comb-over hairstyles in front of a balding man who has one (Marshall 2014). He knows he as a comb-over, the whole world can see he has a comb-over, but no-one dares to talk about it front of him (Marshall 2014). This phenomenon plays out in the absence of conversations between individuals regarding what each is going to actually do to play our part in saving our future generations from living through climatic upheaval. In a similar vein, in a presentation to the International Congress of Applied Psychology, titled "Seven Dragons of Inaction – Why We Do Less Than We Should", Prof Robert Gifford builds the discussion about the human aspects that create the information to action disjoint (Giffard 2010). Gifford describes 7 aspects of the human psyche that have influence:

1. Limited Cognitions.

Namely that the changes that are occurring around us are very hard to perceive, not enough knowledge, too much conflict in information from science, and events that happen far away from us in location or time are discounted heavily, giving preference to immediate events.

2. Other people

While the media has influence over us, our concerns of what other people think of us and how we compare to life-long social norms is more powerful. As activism and early adopters gain strength, people's actions encourage us to follow suit.

3. Perceived Risks

People tend to be risk averse, and so decisions to embrace change tend to be difficult because of concern how the unknown factor may impact the outcomes of change.

4. Sunk Costs

Prior actions, decisions and investments can make it difficult to change because the change may require us to give up what we have previously valued.

5. Ideology

If a change requires us to act in a way that our currently held view of the world would have us behave, further barriers to change exist as it may mean admitting that we were wrong about previously held convictions.

6. Discredence

Our level of distrust (in a political structure, science, institution or even individual) we will be reluctant to go along with it.

7. Limited Behaviour

Our ability to see how our actions will make a difference comes into play here, as does not being able to see options of how to respond because we have never done this before. Other aspects also come into play such as innocent tokenism (taking action that involves changes that ultimately cost more than the benefits of the change – such as was one argument of alternative power systems that require lead-acid batteries). Being provided information of the highest impacting actions can help here (Giffard 2010).

George Marshall sums the situation up, by saying how it would be different if an external enemy existed, say, North Korea deciding to poke huge volumes of known pollutants into the air in order to destroy the global climate (Marshall 2014). The uniformity and level of our response would be very different. But this is not the case, there is no single external enemy to focus on, it is internal and it is all of us. Our ability to come to terms with this is the difference between whether we reach to optimistic 1.5°C increase or pass the supposed tipping 4°C point.

That global warming from climate change brought about from greenhouse gases as by-products of human activity is really no longer disputed. Nor is the fact that action is required in order to mitigate unprecedented environmental impact upon future generations.

In the process of science framed in a way that is accessible to the general public, more people will see the complexity and evolution of climate research for what it is, i.e. evolving and very complex science. Regardless of the level of decision makers, strong “people’ barriers need to be more deeply recognised, understood and managed in order for people around the world to see that climate change is not in the future, it is now, and the impact will significantly impact every single one of us (with certainty) so that we can own or role in mitigating the impact on future generations.

As to whose role this is? It is the responsibility of every single individual who understands the situation for what it is, and that responsibility starts with recognising the many options we have right now and acting upon them in a way that is appropriate to the situation. It is up to these people who sufficiently understand the science, to understand the barriers and start to break them down by initiating conversations with other people (starting with those closest to us). Quite possibly, the people who must lead this change are the very scientists that understand it.

However, at this stage, politics plays an extremely large role in how climate change may be mitigated which by itself, can have many impacts on the science in terms of what can be done and also what is to be done about it.

### *Actual and the Potential Political Impacts of Antarctic Climate Change Research*

Humans are inherently political. There are seldom few issues that are void of any political influence or consideration. Antarctic research is not exempt from this universal qualification. Climate change research is one of the primary areas of research that occurs within Antarctica. The legal framework of the Antarctic Treaty System (ATS) creates an atmosphere of collaboration and cooperation. Relationships between countries are essential to the delivery of sound comprehensive science. Political decision makers may not always view the science with the same reverence that scientists do. However, climate change is an area of research that has compelled international action and advocacy within national citizenry. This has a tangible political impact.

#### *Political Atmosphere*

In order to determine the actual and potential political impacts there must be a context within which the analysis is made. There are a myriad of nations throughout the world that conduct climate change research, which invariably has some bearing on the Antarctic. Conducting observations that could be made about all these different countries political and scientific contexts would be an enormous undertaking beyond the ambit of this report. As New Zealand is the most pertinent to the faculty that this research is being pursued, all commentaries will be made in reference to a New Zealand context.

The current National Government has been in power since 2008. The closest policy decision-making paradigm that could characterise the National Party would be neo-liberalism. At its foundation, this policy is market driven. Primarily, industry and economic development determine the decision-making. This was first introduced in New Zealand in the mid-1980's with the widespread reforms of the Fourth Labour Government. This has not changed remarkably in the years to present. However, the credit crunch and eventual global financial crisis in 2008 put substantial strain on this policy ideology. In response, fiscal austerity had to be put in place. This meant a reduction in investment and spending in the public sector which includes the state contributions to science and research. The market controls that had to be put in place were not neo-liberal as that ideology advocates for minimal market controls. Rather, a Keynesian interventionist policy approach was taken. This has not been successful as the National Government have only posted a surplus one-quarter out of the every quarter they have been in power. A failure to adopt the associated Keynesian tax reforms and public sector reforms has meant that the neo-liberal mixed approach has increased national debt to record levels and science funding has suffered adversely as a result. As a market based economy, primary resources are the driving impetus behind investment and growth. Many of these industries are supported by fossil fuels and other greenhouse gas emitting components such as livestock and fertiliser production. Recent international negotiation was conducted in Paris at the Climate Conference of the Parties 21. This has increased the domestic and international pressure on politicians to consider the resources that drive their economies and how to reduce their emissions profile. Antarctic climate change is a driver of the world's environment in many ways resulting in a larger degree of gravitas placed on the research that is carried out. Trade agreements are at the priority of foreign ministers instead of climate change agreements. This is primarily a result of the pressures to recover from the global financial crises as well as the performance of a market based economy. Many Western governments are currently a majority conservative representation. Conservative governments are less likely to give precedent to climate change policy as it affects the myriad of interest and lobby groups that support them as well as the emissions producing industries that canvas their economic portfolio. Many opposition governments are still characteristically centric instead of left wing. This results in a poorer discuss around the actions that need to be taken as a result of climate change research as it negatively affects their economic support base. Without a strong vocal opposition, current conservative governments have little political pressure to take the necessary mitigation and investments needed to respond to Antarctic climate change research.

### *Funding*

Funding is a challenge given the severity of the global financial crisis. With austerity measures still firmly in place and a budget that is consistently deficit, prioritising science has not been a policy pursued by the government. Although the new Ministries and Crown research institutes such as the New Zealand Antarctic Research Institute have condensed previous ministries into new 'super ministries', the budgets are a gross increase but a net decrease once inflation is taken into consideration. Whilst collating the specific amounts granted annually to each sector of government is possible with annual reports and Treasury documents, determining the amounts spent on climate change and then separating Antarctic climate change is near impossible and worthy of an extended study. The pool of money available is divided across the public sector, but a general estimate is \$17 million for logistical science support and approximately \$8 million from Crown research institutes, universities and the Ministry of Business, Innovation and Employment. Given the substantial outputs by researchers in New Zealand about climate change in Antarctica, this budget has gone considerably far given the expense of scientific endeavour in the Antarctic. Future areas of funding could come from industry. The fishing industry already conducts measurements in the Ross Sea and there are opportunities to expand on that to make use of the vessels that are already in region.

Likewise with tourism operators who have been increasing year upon year in the scale and range of their activities offered in the Southern Ocean and Antarctic continent. Philanthropy is another area. Private investors have been involved in Antarctica since the first expeditions. There are large economic reserves held by just a few individuals many of whom are approaching retirement. Making the most of these substantial wealth reserves for the benefit of humanity and science should be a priority for sourcing new funding for climate change research including the Antarctic.

### *Actual Impacts*

Determining the actual of Antarctic climate change research is not a simple task. Decision-makers need to be informed before making decisions that may impact the economy and the wellbeing of citizens. Much of the Antarctic research is settled in that the continent is changing rapidly and the temperature is increasing with consequent impacts on the meteorology and marine systems that may have an adverse effect on New Zealand. What is not present in the research is the definition needed to project and plan the decisions that may be necessary. Putting budget and resources aside to take mitigation actions such as placing emissions duties on agriculture is politically unattractive and open to criticism as the research cannot at this stage state with authority that the Antarctic climate will be devastated within 20 years if action isn't taken. Agriculture is still exempt from the no-cap emissions trade scheme despite contributing to nearly 50% of our national greenhouse gas emissions. The media can capitalise on this acute lack of knowledge to drive the debate that climate change does not need priority action. The research conducted around the world, including Antarctica points to the contrary but this lack of definition is an issue in creating urgency in decision-making. If the media continue to incorrectly portray the research with inappropriate headlines and archaic debates about authenticity then public sentiment is unlikely to cause widespread and representative pressure on politicians. As the political cycle is 3 years, public sentiment becomes important as big mistakes can cost the next election, as it will still be relatively recent in the public conscience. If the public are uninformed and the effects of climate change are not felt adversely on a continual basis, any widespread pressure is unlikely to eventuate. Consequently, Antarctic climate change research is not made a priority as the challenges it presents can be addressed in the future once the political pressure is such that action must be taken. Even then, New Zealand is a small contributor to global emissions and does not have the resources to put towards research that a nation like the United States does. This makes the importance of using science as a currency of diplomacy essential. By drawing upon and building the relationships with other states on the basis of research, collaboration can yield greater results at a lower cost to all parties in particular the smaller parties such as New Zealand.

### *Potential Impacts*

The potential political impacts are varied. As politics is able to find its way into almost all aspects of human life, it is arguable that essentially everything is potentially impacted. However, some key potential impacts are identifiable. There may be an increase or decrease in the funding allocated to Antarctic climate change research. If the research is deemed to be essential at the current time to decision-makers then it may be that further resources are set aside and invested in Antarctic research. This may be directly through research grants or indirectly through science diplomacy. A decrease may come about if the current economic environment persists. Given the lack of funds available to the government and the record amount of sovereign debt accumulated over the past decade, it may be unlikely that a significant portion of funding is put forward for further research and that in fact the amount of funding remains the same or is marginally increased which in real terms is a decrease in funding due to inflation. The public may very well start to increase the pressure that they apply to politicians as their expectations of what they want New Zealand to do in

response to climate change is not met by politicians. In that instance, in order to remain in power the politicians would have to alleviate the concerns of the citizens by taking action. This would be driven through climate change research such as that done in Antarctica. Industries and jobs are at stake with any consequential policies as a result of climate change research. Agricultural practices and resource industries as well as our transport networks depend heavily on fossil fuels and result in undesirable greenhouse gas emissions. If the research creates a need to change these practices then these industries and their associated jobs will be threatened. However, there may also be opportunities for new industries and jobs to emerge as the technology enables adaptations and expansion into alternative mechanisms to drive our economy. Strategic relationships may become essential to driving new research and supporting programmes as well as adaptations that need to be made in response to climate change research. This could bring nations together that may otherwise have not seen the need or alignment that exists using science diplomacy. Existing international relationships could be strengthened as nations reaffirm their allegiance and support of one another. This could potentially create international tension as some nations could be at odds with others and a new alliance system emerges. Equity amongst nations participating in Antarctica and the contributions to climate change could be a factor for increasing these tensions.

### *Conclusion*

Antarctica was once described by President Clinton as a 'as a bridge to our future and a window to our past'. As an archive, the continent can provide a substantial resource as to what life was like on our planet thousands to millions of years ago. As an indicator, the indigenous species and ice that surrounds the continent exist in a delicate balance, which is highly susceptible to climate change and can be used to track wide ranging global effects.

The science being produced from this region also provides robust predictions for future climate effects and the challenge is therefore how to communicate this information to populations and policy makers from different countries, economic backgrounds and social standings. Progress has been made in a number of areas including political buy in from the signing of the Paris protocol at the recent COP21 meeting. Local and national governments are also taking the issues of climate change and their immediate implications more seriously and the science and issues related to the topic are generally broadly understood in most western counties. The topic will appear on numerous school curriculums and various national and international action groups, societies and media organisations are actively involved in communicating the important messages Antarctic science is telling mankind.

In addition, with regard to the potential and actual political impact of Antarctic climate change research this is not a simple or objective topic. There are a myriad of opinions that differ depending on political alignment and the perspectives taken. The existing government is not in a position to make this area of research a priority however efforts can be made if the economy is corrected given that the economy is what drives current government decision-making. The research is fairly settled however and at some stage political action will need to be taken.

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