**PCAS 20 (2017/2018)**

**Critical Literature Review**

**(ANTA602)**

# Antarctica’s Fifth Age? Some supporting evidence

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**Abstract**

Ten years ago, Alan Hemmings proposed that Antarctica had entered a Fifth Age identified by a much more complex global context. This paper examines evidence from recent biophysical and socio-economic literature on the Antarctic which show an increasing number of papers identifying changes which appear, at least in part, to be attributable to global change processes. These are often in highly specialised topics that are identified as exhibiting early stages of potentially significant transformations with specific changes mooted and, in some cases, projected out several decades or more. Collectively these provide early indications of a shift to the Anthropocene, estimated, by some sources, as having started in the post-war period and coinciding with establishment of the Antarctic Treaty and the concept of setting Antarctica aside for peace and science. Papers published over the last decade or so have been selected that identify specific significant changes in Antarctica in the coming decades as identified by PCAS presenters. The papers are classified according to the criteria established in the global climate change scenarios architecture. The review then identifies that there is evidence of a Fifth Age but that it needs much more nuanced research than thisinitial overview.

# The notion of a Fifth Age

*“The Antarctic regime does not face imminent collapse, but its apparent calm disguises significant ecological and geopolitical instability. …. the picture of human activity in Antarctica has transformed from one still heavily terrestrially focused, dominated by national Antarctic programmes, largely science focused, and situated within Cold-War geopolitics, to one where diverse activities, increasingly including the marine environment, involving a much wider group of actors and commercial imperatives, is the norm. Globalism has brought new pressures, and increased intensity of pressures to Antarctica. (Hemmings, 2009: 55)*

Almost ten years ago Alan Hemmings proposed that Antarctica had entered a Fifth Age (2009:57) around 1990. Hemmings had defined the earlier four epochs as:

* Speculation and conjecture on its existence from antiquity to the early modern era
* Maritime discovery from the late 18th to early 19th centuries
* Heroic Age from early 20th century to the inter-war years
* Science Continent from post WWII to present day

This Fifth Age would be marked by an Antarctic dominated by the challenges of globalism through resources exploitation, commercial interests and weak governance mechanisms.

This paper reviews evidence to support this claim. It includes concepts arising from the impacts of anthropogenic climate change and the concept of the Anthropocene (Waters et al., 2016). If the evidence does distinguish the notion of a Fifth Age then claims by Hemmings and others, such as Scott (2010), that new institutional arrangements need to be in place well in advance of any review of the Antarctic Treaty System may be increasingly defensible. If the evidence is less persuasive then the arrangements developed since the 1950’s may be considered future-proofed for subsequent decades.

Before examining potential evidence the paper seeks a plausible framework by which to determine if a continent has passed from one sociocultural age to another[[1]](#footnote-1). Given that climatic change provides the backdrop to any change of epochs, it is reasonable to draw on that literature for a possible architecture and modify it to the task in hand and into which contemporary science can be accommodated.

Recent literature discusses future possibilities for the Antarctic from multiple perspectives including, inter alia, climate change, potential resource exploitation and increased tourism (Liggett, Frame, Gilbert, & Morgan, 2017). This review seeks to summarise some high-level future trends from the scientific literature across multiple domains as part of a recognised global architecture and then to examine what these, together, present as a narrative about this proposed Fifth Age. Finally the paper identifies what is needed to examine these claims further.

# 2 Age Classification: provisional Antarctic categories and elements

To provide structure to an enormously broad set of topics, the review draws on recent work on climatic change scenarios to source an overall framework in which all global topics can be situated (Ebi, Kram, van Vuuren, O'Neill, and Kriegler (2014); Vuuren et al. (2014)). This makes use of nine categories and 24 elements derived to develop meaningful global and regional climate change scenarios under a structure as shown in Table 1 (O’Neill et al., 2017). As these were developed for application to global, regional and national scenarios including parts of the world with high population densities with significant developmental issues and high levels of resource exploitation, they are much broader than those needed for the Antarctic. However, as they are increasingly used as a means of defining global, regional and national scenarios for climatic change by the Intergovernmental Panel on Climate Change (IPCC) and researchers, they have a global currency that makes their adaptation to the Antarctic an attractive option.

The categories and elements in Table 1 are very comprehensive and include elements heavily focussed on social and economic aspects of human society. It is argued that Antarctica’s unique environment and status under the Antarctic Treaty System (ATS) requires a modified set of elements under the same categories. An initial set of elements are shown in Table 2 based on a brief examination of current research. These will change as new material becomes available. At this stage, they are indicative rather than exhaustive. It is also noted that the number of references cited represent a very small fraction of the total global research output on the Antarctic and that, inevitably, some key papers may have been neglected or omitted.

# 3 Assessing some recent literature

Even with only a handful of papers identified in each category and element, detailed analysis is outside the scope of the current review. However high-level trends have been identified and are summarized below by category in the order given in the original framework with a brief comment on a possible shift from the Scientific Age. For the purposes of this review a shift to a Fifth Age would be marked by the incluson of factors relating to the much more complex institutional environment in which the research is situated and the extent to which it is accomodated into research objectives.

## Demographics

The growing population of science-related staff living in Antarctica is assessed through COMNAP’s published data[[2]](#footnote-2) on the number of beds available in summer at all permanent stations from the date at which each station was opened (Figure 1). The graph does not make allowance for expansion or contraction of bases over time and the extent to which these bases currently reach full capacity or the extent to which they are used over winter. However, the trend is clear, although the jump in 1956 due to the opening of McMurdo station, should be spread over a number of expansions in the intervening years. If a similar rate of growth were to continue to 2049 (i.e. when the current ATS can potnetially be reviewed) then a notional total summer population of, say, 7-8,000 is not inconceivable, especially with countries such as China planning a perennial base at Inexpressible Island with a proposed summer staff of 80 (Brady, 2017) by 2022[[3]](#footnote-3). While numbers are increasing, especially with those over-wintering, it is unclear if there is a step-wise change towards a Fifth Age or indeed if this is a reasonable metric for a Fifth Age.

## Economic development

The following activities are considered as the principal components of economic interests in the Antarctic: science, fishing, tourism, bioprospecting and potential future resources exploitation.

* **Science** is clearly at the heart of the current Antarctic paradigm and as such a key economic element of the continent. In the last few years future directions have been reviewed and key research questions proposed. Of these, the six proposed by M C Kennicutt et al. (2014) the most interesting is the inclusion to ‘Recognize and mitigate human influences’ which marks a shift to more anthropogenic considerations

At first pass, these comply quite easily with the notions of a Scientific Age devoted to production of new knowledge. However, the sixth direction opens up inquiry to the concept of anthropogenic change and with that it becomes, under more careful examination, very obvious that the first four are also directly implicated with global change processes. This is the fulcrum which may tip the argument for a Fifth Age and which is consistently repeated in other elements.

* **Fishing** has been a constant activity in Antarctica well before it became the continent of ‘peace and science’. It is perhaps the sector that has gone through the most change with the move from whaling and sealing through extensive krill fishing and with the more recent declaration of Marine Protected Areas (Sandersfeld, Davison, Lamare, Knust, & Richter, 2015; Seebacher, Davison, Lowe, & Franklin, 2005). It is likely to continue to be a major topic relating to economic development and to the future of the continent though it is bioprospecting that is more likely to be the source of a step change.
* **Tourism** numbers have been expanding considerably over the last two or so decades largely through sea-based numbers. As a field of study this has developed its own rich literature though there is only a small number of publications focusing on long-term future impacts relating to Antarctica (Liggett et al. (2017); Liggett, McIntosh, Thompson, Gilbert, and Storey (2011); Stewart, Liggett, and Dawson (2017); Amelung and Lamers (2006); Student, Amelung, and Lamers (2016)). However, tourism is a very dynamic commercial activity, and it is likely that the composition of tourism numbers will shift with developments in the market, including new opportunities elsewhere such as deep-sea, outer space etc. However, as with Everest, the ‘third’ pole, it is unlikely that overall tourism interest will drop in the near future (Elmes & Frame, 2008). In summary, tourism is so intrinsically linked to anthropocentric issues that anything other than a moratorium on tourism, for which there appears no appetite, supports the notion of a Fifth Age.
* **Bioprospecting** is a potential indicator of a shift to a Fifth Age (Cunningham-Hales, 2017; Jabour, 2013). The projection for bioprospecting for krill patents is now close to 1000 and has doubled over15 years. As such it is a significant topic for the future of Antarctica. This is a major potential Fifth Age topic.
* **Mineral exploitation** This is an excluded activity under the ATS and can only be considered after 2048 through various complex processes if the majority of ATS signatories considered such a change under the Protocol. This appears to be a long way off and may be overtaken by other options such as near-earth asteroid mining (Elvis, 2012). So, although this was part of Hemmings’ (2009) original thesis, it now seems less likely.

## Welfare

While human development, education and health are obviously highly impacted by climate change especially in developing countries, the topic of welfare has much less salience in Antarctica. This is especially so considering that both main groups of visitors (the research community and tourism (including adventurers)) currently enjoy services much improved since the Heroic Age. While this may change with increasing numbers wintering over and an extending tourism season, no research has been found to document this topic though some is currently being undertaken (Gary Steele, pers. comm. 2017). As such this is not considered sufficiently material and is not considered further.

## Environmental and ecological factors

Given the high level of Antarctic scientific activity, there is a large volume of papers examining shifts in terrestrial and marine environments. However, multiple results indicating very marked and irreversible shifts often attributed to global change processes provide strong evidence of a Fifth Age. These include but are not restricted to:

* **Biodiversity** ((Steven L Chown, 2013; Steven L. Chown et al., 2015; Steven L Chown et al., 2012); Convey, 2011; Hogg & Wall, 2011; Steven L. Chown et al. (2015)); including Emperor penguins (Jenouvrier, Garnier, Patout, & Desvillettes, 2017; Jenouvrier et al., 2014) and Adelie penguins (Fraser, Patterson-Fraser, Ribic, Schofield, and Ducklow (2013))
* **Ecosystem services** (Castendyk, Obryk, Leidman, Gooseff, and Hawes (2016))
* **Oceanography including freshening of the Southern Ocean** (Joughin, Smith, and Medley (2014));
* **Marine ecological processes** (Sandersfeld, Davison, Lamare, Knust, & Richter, 2015); (Seebacher, Davison, Lowe, & Franklin, 2005)

Collectively these indicate ecosystems are undergoing considerable change of which one major factor is the impact of climate change though it should not be separated from a much more complex set of global change processes. The aforementioned papers describe research more related to rapid change processes rather than fundamental knowledge. The immediate impacts and implications are often described and, in some cases, projected out by up to several decades, for example: species migration or decline; shifts in oceanographic trends; or changes in ecosystem services. It is, however, less clear how the various researchers view longer-term resolution.

## Resources

The main topic here is freshening of the Southern Ocean though there are overlaps with fish stocks; bioprospecting and mineral resources which are considered under economic and technological development. Freshening is an overall reduction in thermal mass and density of the Antarctic Bottom Water (ABW) that has been investigated for several decades (Menezes, Macdonald, & Schatzman, 2017; Purkey & Johnson, 2013; Turner et al., 2013). These papers suggest that the shifts that are occuring in the composition of the Southern Ocean are attributable to anthropogenic issues and that these are of a complexity not previously anticipated.

## Institutions and governance

The main element here is the governance of Antarctica and the extent to which it is either shifting in purpose from that established in the 1950’s at the start of the Scientific Age, or is considered to be in need of extensive reform (Hemmings, 2018; Scott, 2010; Summerhayes, 2015; Tina Tin, Liggett, Maher, & Lamers, 2013). While the Treaty is open-ended, the concerns raised do suggest that its future is not entirely straightforward. However insititutions take time to change. It is not easy to envisage a process by which very significant change will take place other than through some form of global crisis. Without this it is not really feasible to anticipate a Fifth Age in terms of institutions.

## Technological development

There have been reviews both of the future of science relating to Antarctica (M. C. Kennicutt et al., 2014) and about the impact of future technologies on Antarctica (Hemmings, 2009). These coupled with broader concerns about the future of science do make this an important topic for further consideration. Indeed the main topic may be less to do with Antarctic technology but with a shift in the nature of science and technology globally to a topic referred to, variously, as post-normal science, integrated science, or wicked problems. Given that many of the effects described have anthropogenic origins it may be the case that the research questions need to be considered through these new lenses although that could bring other complications.

## Broader societal factors

This is harder to define as it effectively covers global society’s perspective on Antarctica. At this point of the study, the topic is not discussed further as the main arguments are presented in the other categories. It is, however, held open for future consideration though it could, potentially, combine with the previous two categories.

## Policies

The main element considered here are the broad geopolitical importance of Antarctica on the global stage. There is increasing jostling for positon in the Antarctic whether it be through apparent indigenization by Chile and Argentina, through the increasing ATS membership (both signatory and non-signatory), or the increasing interest by China to affirm itself as a Great Polar Power. The latter probably has the greatest influence on a Fifth Age with the possibility that it become its greater actor. Perhaps the biggest hindrance on effective research on China’s interests is the effective separation between internal (‘*neibu*’) and external (‘*waibu*’) facing policy discourse (Brady, 2017). However, the growing pressure on Antarctica is a distinct move away from an empty continent devoted solely to peace and science towards a Fifth Age (T. Tin et al. (2008); Turner et al. (2013); Wadham et al. (2013) Hemmings (2009); Scott (2010)).

# 4 Concluding comments and future work

While the material cited here is but a brief glance at a much larger body of work, it seems reasonable to concur with Hemmings (2009) that a very significant change is taking place in the Antarctic coincidental with his notion of a Fifth Age. Furthermore, the thesis promoted by Tina Tin et al. (2013) that there is a need for development of the overall institutional arrangements for the Antarctic at least requires a thorough review and, potentially supports a move to some form of deliberative exceptionalism (Hemmings 2009) or other arrangements Scott (2010). While theoretically sound, such a shift in governance processes may not be a practical solution. A shift in overall science direction may be more likely especially if this were accompanied by a shift to new research paradigms as is being increasingly discussed (Saltelli & Funtowicz, 2017).

How might such changes be structured for the Antarctic? Gilbert[[4]](#footnote-4) has outlined risks between the assets of the Scientific Age, namely:

* Quality and timeliness of decision making
* Availability of data and information
* Strategic thinking and prioritisation
* Political will

and the priorities determined by changing circumstances, namely:

* Climate change
* Introduction of non-native species
* Human impacts
* New Treaty members
* New value sets

With this in mind, it is reasonable to anticipate that evidence of an emerging Fifth Age would primarily be present in the academic discourse. Two secondary datasets should also be considered. The first is publically available promotional material (videos, brochures, websites, etc.) produced by COMNAP members since 2010. These are anticipated to be futures-focussed and aspirational in content and provide insights on how nation states are choosing to express their vision for the future of the Antarctic. The second would be items focussed on Antarctic futures through film and literature produced since 2010 as catalogued through, for example, the UTAS ‘Representations of Antarctica’ bibliography. Collectively these three datasets could be analysed using basic discourse analysis techniques that would provide an illuminating insight into possible Antarctic futures.

It is important to review the suitability of the categories and elements for application in Antarctica and to continue to add more citations as they arise.

Data needs to be mapped against published scenarios (Liggett et al., 2017). Analysis should involve a brief discourse analysis to identify possible motivations and responses about long-term implications. If the Liggett et al. (2017) scenarios are validated by the analysis, their scenarios could, in turn, be evaluated using the Circles of Sustainability framework (James, 2014). Alignment (or otherwise) between the datasets will be discussed as a possible indicator of future conflicting worldviews.

Finally, there is the issue of pragmatics. While the increasingly overwhelming evidence about global change processes may best be tackled in theory through new governance and institutions, it does appear not to be matched by an marked appetite for reform in any of the global institutions. Multi-lateral agencies are dogged by slow processes, a need to build consensus and an inevitable inertia while lacking any immediately obvious champion of change. The risk of failure may well outweigh the possibility of success. If that is indeed the case, then it may be necessary to see the Antarctic’s issues as yet another wicked problem without a feasible solution. In so doing, it may be that declaring a Fifth Age without overhauling governance wholesale yet improving institutional transparency and accountability could be the best opportunity available. It is likely that it would require much greater understanding of how best to work with wicked problems than is current practice. This, in turn, could become a defining research characteristic of a Fifth Age. Welcoming a New Age baby while retaining the bathwater of the Scientific Age may well be the only feasible option.

# References

Amelung, B., & Lamers, M. (2006). Scenario development for Antarctic tourism: Exploring the uncertainties. *Polarforschung, 75*(2/3), 133-139.

Brady, A.-M. (2017). *China as a Polar Great Power*. Cambridge: Cambridge University Press.

Castendyk, D. N., Obryk, M. K., Leidman, S. Z., Gooseff, M., & Hawes, I. (2016). Lake Vanda: A sentinel for climate change in the McMurdo Sound Region of Antarctica. *Global and Planetary Change, 144*(Supplement C), 213-227. doi:<https://doi.org/10.1016/j.gloplacha.2016.06.007>

Chown, S. L. (2013). Antarctic treaty system past not predictive. *Science, 339*(6116), 141-141.

Chown, S. L., Clarke, A., Fraser, C. I., Cary, S. C., Moon, K. L., & McGeoch, M. A. (2015). The changing form of Antarctic biodiversity. *Nature, 522*, 431. doi:10.1038/nature14505

Chown, S. L., Lee, J., Hughes, K. A., Barnes, J., Barrett, P., Bergstrom, D. M., . . . Dyer, G. (2012). Challenges to the future conservation of the Antarctic. *Science, 337*(6091), 158-159.

Cunningham-Hales, P. (2017). Why is the Regulation of Bioprospecting in Antarctica Lacking and What Could the Future Hold.

Ebi, K. L., Kram, T., van Vuuren, D. P., O'Neill, B. C., & Kriegler, E. (2014). A New Toolkit for Developing Scenarios for Climate Change Research and Policy Analysis. *Environment: Science and Policy for Sustainable Development, 56*(2), 6-16. doi:10.1080/00139157.2014.881692

Elmes, M., & Frame, B. (2008). Into hot air: A critical perspective on Everest. *Human Relations, 61*(2), 213-241. doi:10.1177/0018726707087785

Elvis, M. (2012). Let's mine asteroids--for science and profit: the commercial dream of trawling space for valuable minerals could bring enormous benefits to a wide range of sciences. *Nature, 485*(7400), 549-550.

Fraser, W. R., Patterson-Fraser, D. L., Ribic, C. A., Schofield, O., & Ducklow, H. (2013). A Nonmarine Source of Variability in Ad&#xe9;lie Penguin Demography. *Oceanography, 26*(3), 207-209.

Hemmings, A. D. (2009). From the New Geopolitics of Resources to Nanotechnology: Emerging Challenges of Globalism in Antarctica. *The Yearbook of Polar Law Online, 1*(1), 55-72. doi:doi:<https://doi.org/10.1163/22116427-91000007>

Hemmings, A. D. (2018). The Hollowing of Antarctic Governance. In P. S. Goel, R. Ravindra, & S. Chattopadhyay (Eds.), *Science and Geopolitics of The White World: Arctic-Antarctic-Himalaya* (pp. 17-31). Cham: Springer International Publishing.

Jabour, J. (2013). Biological prospecting in the Antarctic: Fair game?

James, P. (2014). *Urban sustainability in theory and practice: circles of sustainability*: Routledge.

Jenouvrier, S., Garnier, J., Patout, F., & Desvillettes, L. (2017). Influence of dispersal processes on the global dynamics of Emperor penguin, a species threatened by climate change. *Biological Conservation, 212*, 63-73.

Jenouvrier, S., Holland, M., Stroeve, J., Serreze, M., Barbraud, C., Weimerskirch, H., & Caswell, H. (2014). Projected continent-wide declines of the emperor penguin under climate change. *Nature Climate Change, 4*(8), 715-718.

Joughin, I., Smith, B. E., & Medley, B. (2014). Marine Ice Sheet Collapse Potentially Under Way for the Thwaites Glacier Basin, West Antarctica. *Science, 344*(6185), 735-738. doi:10.1126/science.1249055

Kennicutt, M. C., Chown, S. L., Cassano, J., Liggett, D., Massom, R., Peck, L., . . . Wilson, T. (2014). Six priorities for Antarctic science. *Nature, 512*(7512), 23-25.

Kennicutt, M. C., Chown, S. L., Cassano, J. J., Liggett, D., Peck, L. S., Massom, R., . . . Sutherland, W. J. (2014). A roadmap for Antarctic and Southern Ocean science for the next two decades and beyond. *Antarctic Science, 27*(1), 3-18. doi:10.1017/S0954102014000674

Liggett, D., Frame, B., Gilbert, N., & Morgan, F. (2017). Is it all going south? Four future scenarios for Antarctica. *Polar Record, 53*(5), 459-478. doi:10.1017/S0032247417000390

Liggett, D., McIntosh, A., Thompson, A., Gilbert, N., & Storey, B. (2011). From frozen continent to tourism hotspot? Five decades of Antarctic tourism development and management, and a glimpse into the future. *Tourism Management, 32*(2), 357-366. doi:<https://doi.org/10.1016/j.tourman.2010.03.005>

Menezes, V. V., Macdonald, A. M., & Schatzman, C. (2017). Accelerated freshening of Antarctic Bottom Water over the last decade in the Southern Indian Ocean. *Science Advances, 3*(1). doi:10.1126/sciadv.1601426

O’Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., . . . Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change, 42*, 169-180. doi:10.1016/j.gloenvcha.2015.01.004

Purkey, S. G., & Johnson, G. C. (2013). Antarctic Bottom Water Warming and Freshening: Contributions to Sea Level Rise, Ocean Freshwater Budgets, and Global Heat Gain. *Journal of Climate, 26*(16), 6105-6122. doi:10.1175/jcli-d-12-00834.1

Saltelli, A., & Funtowicz, S. (2017). What is science’s crisis really about? *Futures, 91*(Supplement C), 5-11. doi:<https://doi.org/10.1016/j.futures.2017.05.010>

Sandersfeld, T., Davison, W., Lamare, M. D., Knust, R., & Richter, C. (2015). Elevated temperature causes metabolic trade-offs at the whole-organism level in the Antarctic fish <em>Trematomus bernacchii</em>. *The Journal of Experimental Biology, 218*(15), 2373-2381. doi:10.1242/jeb.122804

Scott, K. N. (2010). Managing Sovereignty and Jurisdictional Disputes in the Antarctic: The Next Fifty Years \*. *Yearbook of International Environmental Law, 20*(1), 3-40. doi:10.1093/yiel/20.1.3

Seebacher, F., Davison, W., Lowe, C. J., & Franklin, C. E. (2005). A falsification of the thermal specialization paradigm: compensation for elevated temperatures in Antarctic fishes. *Biology Letters, 1*(2), 151-154. doi:10.1098/rsbl.2004.0280

Stewart, E. J., Liggett, D., & Dawson, J. (2017). The evolution of polar tourism scholarship: research themes, networks and agendas. *Polar Geography, 40*(1), 59-84. doi:10.1080/1088937X.2016.1274789

Student, J., Amelung, B., & Lamers, M. (2016). Towards a tipping point? Exploring the capacity to self-regulate Antarctic tourism using agent-based modelling. *Journal of Sustainable Tourism, 24*(3), 412-429. doi:10.1080/09669582.2015.1107079

Summerhayes, C. P. (2015). Polar science strategies for institute managers. *Polar Record, 52*(2), 239-248. doi:10.1017/S0032247415000716

Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., . . . Snape, I. (2008). Impacts of local human activities on the Antarctic environment. *Antarctic Science, 21*(1), 3-33. doi:10.1017/S0954102009001722

Tin, T., Liggett, D., Maher, P. T., & Lamers, M. (2013). *Antarctic futures: human engagement with the Antarctic environment*: Springer Science & Business Media.

Turner, J., Barrand, N. E., Bracegirdle, T. J., Convey, P., Hodgson, D. A., Jarvis, M., . . . Klepikov, A. (2013). Antarctic climate change and the environment: an update. *Polar Record, 50*(3), 237-259. doi:10.1017/S0032247413000296

Vuuren, D. P. v., Kriegler, E., O’Neill, B. C., Ebi, K. L., Riahi, K., Carter, T. R., . . . Winkler, H. (2014). A new scenario framework for Climate Change Research: scenario matrix architecture. *Climatic Change, 122*(3), 373-386. doi:10.1007/s10584-013-0906-1

Wadham, J. L., De'ath, R., Monteiro, F. M., Tranter, M., Ridgwell, A., Raiswell, R., & Tulaczyk, S. (2013). The potential role of the Antarctic Ice Sheet in global biogeochemical cycles. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh, 104*(1), 55-67. doi:10.1017/S1755691013000108

Waters, C. N., Zalasiewicz, J., Summerhayes, C., Barnosky, A. D., Poirier, C., Gałuszka, A., . . . Wolfe, A. P. (2016). The Anthropocene is functionally and stratigraphically distinct from the Holocene. *Science, 351*(6269). doi:10.1126/science.aad2622

**Figure 1:** Increase in peak population of stations in Antarctica from 1947 to date (Source: [www.comnap.aq](http://www.comnap.aq)). Note: the step increase of 1000 in 1956 is due to McMurdo station which is shown as a single development rather than a series of developments.

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| --- | --- |
| **Category** | **Elements for global climate change scenarios** |
| **Demographics** | Population total and age structure |
| Urban vs. rural populations, and urban forms |
| Other location information, such as coastal vs. inland |
| **Economic development** | Global and regional GDP, or trends in productivity |
| Regional, national, and sub-national distribution of GDP, including economic catch-up by developing countries |
| Sectoral structure of national economies, in particular the share of agriculture, and agricultural land productivity |
| Share of population in extreme poverty |
| Nature of international trade |
| **Welfare** | Human development |
| Educational attainment |
| Health, including access to public health and health care infrastructure |
| **Environmental and ecological factors** | Air, water, soil quality |
| Ecosystem functioning |
| **Resources** | Fossil fuel resources and renewable energy potentials |
| Other key resources, such as phosphates, fresh water etc. |
| **Institutions and governance** | Existence, type and effectiveness of national/regional/global institutions |
| Degree of participation |
| Rule of law |
| **Technological development** | Type (e.g. slow, rapid, transformational) and direction (e.g. environmental, efficiency, productivity improving) of technological progress |
| Diffusion of innovation in particular sectors, e.g. energy supply, distribution and demand, industry, transport, agriculture |
| **Broader societal factors** | Attitudes to environment/sustainability/equity and world views |
| Life styles (including diets) |
| Societal tension and conflict levels |
| **Policies** | Non-climate policies including development policies, technology policies, urban planning and transportation policies, energy security policies, and environmental policies to protect air, soil and water quality. It is possible that SSPs could be specified partly in terms of policy objectives, such as strong welfare-improving goals, rather than specific policy targets or measures. |

**Table 1:** Climate Change Categories and Elements (Source: O’Neill et al. 2014)

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| --- | --- | --- |
| **Category** | **Elements for Antarctica scenarios** | **Fifth Age importance** |
| **Demographics** | Population of bases (total maximum carrying capacity) | Low |
| **Economics** | Science | High |
| Fishing | Medium |
| Tourism | Medium |
| Bioprospecting | High |
| Natural resources and minerals exploitation | Low |
| **Welfare** | Physical and psychological health; medical infrastructure | Low |
| **Environmental factors** | Biodiversity, including megafauna, avifauna and krill | High |
| Ice-sheet and ice-shelf dynamics; and sea ice processes | High |
| Marine ecological processes | ??? |
| **Resources** | Freshening | High |
| **Institutions and governance** | Effectiveness of institutions; participation and legal instruments including geo-political effects | High |
| **Technological development** | Direction of technological progress; role of science in society | High |
| **Broader societal factors** | Attitudes to sustainability, including international tension and conflict levels | Low |
| **Policies** | Climate and non-climate policies relative to the region | High |

**Table 2:** Modified Categories and Elements for Antarctica derived from Table 1 with an initial assessment of the importance of the Category as an indicator of a shift to a Fifth Age

1. Here age or epoch or era are taking to a distinct period of history and the terms are used interchangeably. [↑](#footnote-ref-1)
2. www.comnap.aq [↑](#footnote-ref-2)
3. China Daily, 28 October 2017. [↑](#footnote-ref-3)
4. PCAS 2017/18 presentation 7 December, 2017 [↑](#footnote-ref-4)