Institution: University of Sheffield		
Unit of Assessment: A-05 Biological Sciences		
Title of case study: The use of climate change research as a conduit for international diplomacy and policy in the Arctic		
Period when the underpinning research was undertaken: 2000-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Terence Callaghan	Professor	1995-2020
Gareth Phoenix	Professor	2000-2020
Period when the claimed impact occurred: 2013-2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

Sheffield-based researchers have been at the forefront of climate change research in the Arctic for decades. In addition to their contributions to the scientific community, their ability to bring together researchers from diverse fields, policy makers, and stakeholders including indigenous people has changed the ways in which these groups interact, share, and use knowledge. The creation of these networks has influenced national and international environmental policy, the ability of arctic populations to adapt to and mitigate ecological change, and the general public's understanding of the role of the Arctic in issues related to global climate change.

2. Underpinning research (indicative maximum 500 words)

Since 2000, Professors Terry Callaghan and Gareth Phoenix have produced over 230 publications related to the study of arctic ecology and the effects of climate change. Their prolific and extensive research backgrounds have allowed them to bring together historic and long-term data, field simulations, and local, indigenous knowledge from across the Arctic to create a more complete picture of the impacts of climate change in the Arctic.

Callaghan and an international team have determined that **greater plant growth and biomass due to global warming ("arctic greening") has accelerated from the mid-1990s to the late 2000s**. They have predicted that by the final decade of the 21st century the annual temperature profile for the Arctic will be comparable to that of lands north of 42.4° N (roughly the latitude of Corsica) during the mid-20th century **[R1]**. While a greening arctic has become the prevailing dogma, Callaghan and Phoenix have highlighted the importance of using historic data and local indigenous knowledge to study the unique climatic and land-use impacts at local and regional scales, **which reveals complexities of climate- and human-driven ecosystem change that are challenging to recognise at large scales, thus hindering scientists' ability to accurately predict future changes.** For example, using the area of Abisko, Sweden, Sheffield researchers demonstrated that climate change was not the only driver of vegetation change in the Arctic, and instead the effects of herbivore and human disturbance and short-term extreme weather events are strong drivers of ecosystem change **[R2]**. This was further explored by an international team led by Phoenix (including Callaghan) that combined in-field simulations with landscape observational data to demonstrate the severe damage to arctic ecosystems caused

by extreme winter warming events **[R3]**. This damage is in stark contrast to arctic greening caused by summer warming, and can also interact with other climatic and biotic extreme events (including population explosions of herbivores), which in turn significantly damage ecosystems. **Phoenix and Callaghan have therefore led the step change in understanding away from one of a 'simple' greening arctic to an understanding of ecosystem change that is much more spatially and temporally complex, as recently recognised by the international community [R4].**

Callaghan and Phoenix have illustrated how comparison of different sites within the Arctic region using diverse types of information collected from existing and projected snow datasets is vital for the future of climate change research. Arctic snow cover is one of the most rapidly changing indicators of ongoing climate change. Callaghan, leading an international team of experts, has predicted that the **duration of snow cover will decrease by 10-20% over most of the Arctic by 2050 [R5]**. This is of particular concern for the preservation of the permafrost, native plants that rely on snow to insulate them, and herbivores that will have difficulty accessing food underneath layers of ice formed by additional thawing and freezing. Critically, these changes, along with the ecosystem damage referred to above, are also of direct importance to humans who rely on these landscapes, including indigenous peoples such as reindeer herders and decision makers **[R6]**.

3. References to the research (indicative maximum of six references)

R1. Xu, L., Myneni, R. B., Chapin III, F. S., **Callaghan, T. V.,** Pinzon, J. E., Tucker, C. J., Zhu, Z., Bi, J., Ciais, P., Tømmervik, H., Euskirchen, E. S., Forbes, B. C., Piao, S. L., Anderson, B. T., Ganguly, S., Nemani, R. R., Goetz, S. J., Beck, P. S. A., Bunn, A. G., Cao, C., Stroeve, J. C. (2013). Temperature and vegetation seasonality diminishment over northern lands. *Nature Climate Change, 3*(6), 581–586. https://doi.org/10.1038/nclimate1836

R2. **Callaghan, T. V.,** Jonasson, C., Thierfelder, T., Yang, Z., Hedenås, H., Johansson, M., Molau, U., Van Bogaert, R., Michelsen, A., Olofsson, J., Gwynn-Jones, D., Bokhorst, S., **Phoenix, G**., Bjerke, J. W., Tømmervik, H., Christensen, T. R., Hanna, E., Koller, E. K., & Sloan, V. L. (2013). Ecosystem change and stability over multiple decades in the Swedish subarctic: complex processes and multiple drivers. *Philosophical Transactions of the Royal Society B: Biological Sciences, 368*(1624), 20120488. https://doi.org/10.1098/rstb.2012.0488

R3. Bokhorst, S. F., Bjerke, J. W., Tømmervik, H., **Callaghan, T. V.,** & **Phoenix, G. K.** (2009). Winter warming events damage sub-Arctic vegetation: consistent evidence from an experimental manipulation and a natural event. *Journal of Ecology, 97*(6), 1408–1415. https://doi.org/10.1111/j.1365-2745.2009.01554.x

R4. Myers-Smith, I. H., Kerby, J. T., **Phoenix, G. K.,** Bjerke, J. W., Epstein, H. E., Assmann, J. J., John, C., Andreu-Hayles, L., Angers-Blondin, S., Beck, P. S. A., Berner, L. T., Bhatt, U. S., Bjorkman, A. D., Blok, D., Bryn, A., Christiansen, C. T., Cornelissen, J. H. C., Cunliffe, A. M., Elmendorf, S. C., … Wipf, S. (2020). Complexity revealed in the greening of the Arctic. *Nature Climate Change, 10*(2), 106–117. https://doi.org/10.1038/s41558-019-0688-1

R5. **Callaghan, T. V**., Johansson, M., Brown, R. D., Groisman, P. Y., Labba, N., Radionov, V., Barry, R. G., Bulygina, O. N., Essery, R. L. H., Frolov, D. M., Golubev, V. N., Grenfell, T. C., Petrushina, M. N., Razuvaev, V. N., Robinson, D. A., Romanov, P., Shindell, D., Shmakin, A. B., Sokratov, S. A., Warren, S., Yang, D. (2011). The Changing Face of

Arctic Snow Cover: A Synthesis of Observed and Projected Changes. *AMBIO, 40*(S1), 17–31. https://doi.org/10.1007/s13280-011-0212-y

R6. **Callaghan, T. V.,** Kulikova, O., Rakhmanova, L., Topp-Jørgensen, E., Labba, N., Kuhmanen, L.-A., Kirpotin, S., Shaduyko, O., Burgess, H., Rautio, A., Hindshaw, R. S., Golubyatnikov, L. L., Marshall, G. J., Lobanov, A., Soromotin, A., Sokolov, A., Sokolova, N., Filant, P., & Johansson, M. (2019). Improving dialogue among researchers, local and indigenous peoples and decision-makers to address issues of climate change in the North. *Ambio, 49*(6), 1161–1178. https://doi.org/10.1007/s13280-019-01277-9

4. Details of the impact (indicative maximum 750 words)

International policy and science diplomacy through science evidence and networks

In 2014, Callaghan was a contributing author on the 'Polar Regions; chapter for the Intergovernmental Panel on Climate Change's (IPCC) fifth assessment report (AR5) **[S1]** which included 21 of Callaghan's and Phoenix's publications which were cited 45 times (including **R1**, **R2**, **R3**). The Polar chapter of IPCC was '*discussed at national and international political levels [...] facilitating political discussion and actions on climate change'* **[S2]**. This includes AR5 being used to inform negotiations and policy formulation in the Paris Agreement, COP21, 2015 **[S3]**.

The House of Lords' Select Committee on the Arctic invited Callaghan to provide evidence for their 2014-15 session '*to consider recent and expected changes in the Arctic and their implications for the UK and its international relations*'. They frequently cited Callaghan's evidence regarding arctic science and the UK's role in intergovernmental diplomacy **[S4]**. This session led to recommendations including that the government should (i) appoint a UK Ambassador for the Arctic, (ii) work to insulate Arctic co-operation from non-Arctic disputes, (iii) establish a substantial and better coordinated long-term programme of Arctic research, and (iv) ensure fully effective UK representation on Arctic Council bodies **[S4]**.

Sheffield researchers have brought together disparate Arctic communities and researchers, culminating in the creation of INTERACT by Callaghan (EU-funded, €30M). This pan-arctic network of terrestrial field bases was built by Callaghan from 9 Scandinavian stations in 2013 to now 86 stations across 18 countries. By facilitating and funding access to these stations (900 researchers as of 2019), INTERACT has changed the way research is conducted. Data monitoring, collection, analysis, and communication has been standardised and protocols developed to improve updates on Arctic hazards. Callaghan has created '*an essential service to local communities, national governments and international agencies*' **[S5]** and as a result INTERACT '*has received attention and support from various government embassies and has improved relationships between Russian and Western researchers and infrastructures*' **[S5]**.

Callaghan also helped to establish the Siberian Environmental Change Network (SecNet). The British Embassy in Moscow funds SecNet's workshops, bringing together scientists, policy makers, and indigenous stakeholders from Siberia and worldwide. The 2017 SecNet workshop published resolutions to ensure involvement of these groups in review of existing and new legislation regarding conflict in land-use due to environmental change, for example developing regulations to prevent uncontrolled business activities in the Arctic due to climate change. These resolutions are already being used by Saami reindeer herders in Swedish Lapland to indicate how local people, local authorities and researchers should work together to explore the impacts of increased mining activities on reindeer pasture land **[S6].**

Callaghan's role in facilitating international cooperation has been commended through several awards, including the *International Arctic Science Committee Medal* (2017), for his *'networking and ability to connect large project teams internationally'* **[S7]**, and his appointment of *CMG of the Order of Saint Michael and Saint George* (2018) in recognition of his '*services to advancing knowledge and international collaboration in Arctic science'* **[S8]**.

Working with Arctic communities to make their voices heard in international policy

For many years, Sheffield researchers have collaborated with the Arctic indigenous communities, through joint workshops, research, and involving indigenous representatives in high-level science meetings. Callaghan has been particularly instrumental in the development of shared indigenous knowledge amongst scientists, politicians, and industrialists, and strengthening "*the respect and understanding for traditional knowledge in its context"* **[S9]**. This has allowed indigenous communities to use their "*traditional knowledge to communicate on equal terms with the extractive industries, decision makers and growing businesses such as tourism"* **[S9]**.

In Russia, *'Through meeting with, and helping to unite, indigenous peoples, researchers, health workers, industrial workers, and other relevant groups, Professor Callaghan has helped to establish citizen science in the region, an innovative approach in Russia with substantial potential'* **[S9]**. In Scandinavia, Callaghan has worked with Saami communities and has included them as leaders of work packages in INTERACT so indigenous communities are able to engage with researchers and policy makers more actively and build capacity to adapt to climate change. Scientists and policy makers have also benefited from indigenous knowledge, a joint meeting in Salekhard, Russia in 2017 resulted '*in a paper submitted for publication in an international journal including Indigenous People as co-authors, and the Conference Resolution has already been useful in policy discussions between Saami and local government in Norway'* **[S9].**

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1. Polar regions. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap28_FINAL.pdf).

S2. Letter from Danish Ministry of Climate, Energy and Building describing use of IPCC, ACIA, and SWIPA reports in international climate change policy.

S3. Report of the Subsidiary Body for Scientific and Technological Advice on its forty-first session, held in Lima from 1 to 6 December 2014, VIII.A.2.27**S1** 'International network impacts Arctic research and monitoring' 30.11.2018 European Commission (Horizon 2020 Related Stories) http://ec.europa.eu/research/infocentre/article_en.cfm?artid=49809

S4. House of Lords, Select Committee on the Arctic (2015). Report of Session 2014-15: Responding to a changing Arctic (https://publications.parliament.uk/pa/ld201415/ldselect/ldarctic/118/118.pdf).

S5. 'International network impacts Arctic research and monitoring' 30.11.2018 European Commission (Horizon 2020 Related Stories) http://ec.europa.eu/research/infocentre/article_en.cfm?artid=49809

S6. Report on 2017 SecNet workshop resolutions

S7. International Arctic Science Committee, list of medal recipients (https://iasc.info/medal).

S8. New Year 2018 Honours Diplomatic Service and Overseas List, Order of St Michael and St George, CMG. (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/670945/DS_O_NY18_M_G_HMTQ_FINAL.pdf).

S9. Combined source: Letters from Chairman of Gabna Sámi village, Yamal-Nenets Autonomous Okrug Governor and Director of the Saami Institute of the University of Tromsø and Siida leading Saami reindeer herder describing contribution of Callaghan's research to indigenous community engagement and citizen science.