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A TALE OF TWO SENSORS: AIR QUALITY INDICATOR

Pam McKinlay with Henry Greenslade

INTRODUCING THE RATIONALE AND IDEA TRANSLATION OF THE ICEBERG DEVICE

A small, innocuous object sits in the EPIC[1] office. It is about 5 cm tall, plugs into a computer and the numbers on the display quietly change. It is a carbon dioxide (CO_2) sensor made by Otago Polytechnic Energy Manager Neville Auton. It does its job in a quiet, utilitarian way and is quietly ignored by most, unless the number of people respiring near Neville's desk increases, causing the numbers to spike – at which point, we have our attention drawn to it.

The initial aim of the pilot sensor project was to produce a prototype CO_2 monitoring device by means of which room occupants could track CO_2 levels visually, based on a 'traffic lights' change–alert system. The visual indicator would allow room occupants to notice the status of their current air quality at a glance, and alert them to take responsibility for increasing ventilation and air movement if levels rose above acceptable levels. A separate prototype CO_2 display was built from scratch, designed as an LED panel and also linked to a sensor which displayed values in a readable form. This panel could be deployed inside or outside as part of a broader "New Zealand Environmental Indicator" (NZEI) pilot series, the CO_2 readout being the first off the line. The NZEI are envisaged as a realtime way of relating to RCPs[2] (Representative Concentration Pathways), scenarios which predict sea-level rise and climate-change tipping points.

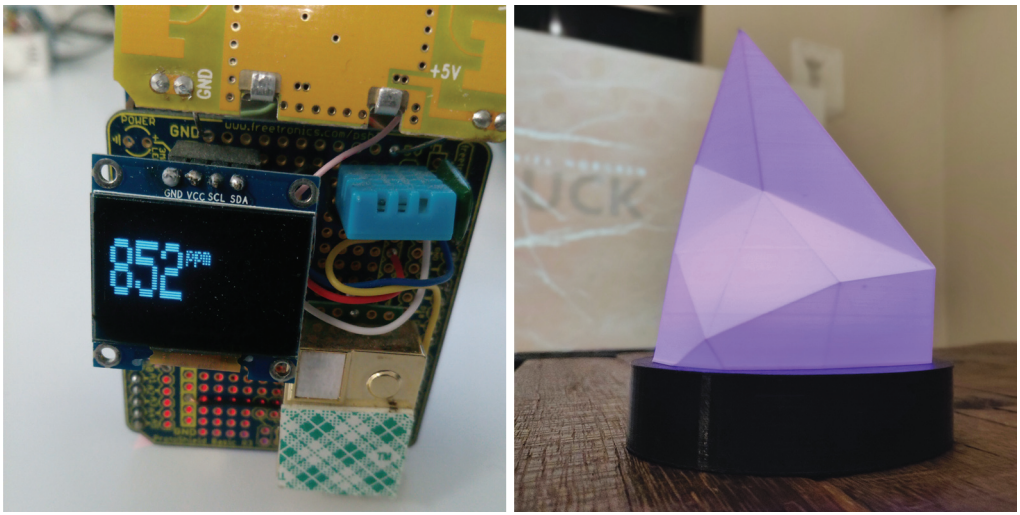

Figure 1. The two sensors. Left: CO_2 desktop sensor made by Neville Auton;
right: CO_2 desktop sensor created by Henry Greenslade as a special topic project for Pam McKinlay, BIT, Otago Polytechnic.

ICE IS COOL – CO_2 IS NOT COOL

What are RCPs? What do the numbers mean and how are they used to predict our future?

RCP (Representative Concentration Pathways) are models of greenhouse gas concentration used for climate modelling. Their primary purpose is to provide scenarios that will predict magnitudes of rising temperatures and sea-level rise.

For example, the lowest level or RCP2.6 scenario assumes that we can achieve net negative anthropogenic greenhouse gas (GHG) emissions after the year 2070 (meaning that we humans absorb more GHGs from the atmosphere than we release). At this lowest curve of the graph, RCP2.6 (green line) carbon dioxide (CO_2) emissions must start declining by 2020 and go to zero by 2100.

At the highest curve, the RCP8.5 pathway (red line), CO_2 concentrations reach around 2000 ppm/v in 2250, with the corollary of **catastrophic** effects on food production and sea-level rise. This is the future of resource scarcity, mass migration, disease and severe weather events, many of which will be unsurvivable and well beyond technological salvation.

The RCPs are also used to predict global sea-level rise. The global mean surface air temperature is the basis of the projection of global mean sea level rise; this figure is projected to rise between 0.24 and 0.82 m by the late twenty-first century (resting sea level height).[3]

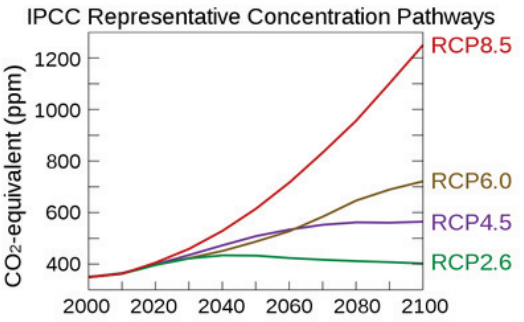

Figure 2. IPCC's AR5 Representative Concentration Pathways used for projecting climate change to 2100. Source: Efbrazil, Wikicommons, CC-BY-SA.

As early as 1873, John Tyndall identified carbon dioxide as having a greenhouse effect by trapping heat in the atmosphere – instead of reflecting it back to space – by closing a gap in the infrared spectrum and powerfully absorbing thermal radiation.[4] The heat trapped in the atmosphere transfers very easily and naturally to the oceans, assisted by water's unusually high capacity to hold and transport latent heat. The IPCC's monitoring of global sea-level rise also looks to paleo records of ice sheets to predict future "Meltwater Pulse" events. The IPCC reports: "Because climate variations during interglacial periods had different forcings from anthropogenic climate change … we do not consider that they provide upper bounds for [sea-level rise] rise during the 21st century."[5] This salutary comment on past climate patterns informs their latest models based on RCP projections:

> As discussed, … there is medium confidence in the ability of coupled ice sheet–climate models to project sea level contributions from dynamic ice-sheet changes in Greenland and Antarctica for the 21st century. In Greenland, dynamic mass loss is limited by topographically defined outlets regions. … By contrast, the bedrock topography of Antarctica is such that parts of the retreating ice sheet will remain in contact with the ocean. Due to topography that is sloping landward, especially in West Antarctica, enhanced rates of mass loss are expected as the ice retreats.[6]

Once the province of speculative fiction writers such as Kim Stanley Robinson, "Meltwater Pulses," as NASA and NOAA scientists agree, not only seem inevitable, but have already begun, and the retreating maxima of Antarctica's sea ice is a glaring warning of global warming and approaching disaster.[7]

In recent studies looking at integrated ice-sheet mass changes, glaciologist Ruth Mottram concludes that **every 1 kg of CO_2 emmissions equates to 12 kg of glacial ice melt.**[8] It has been calculated that this is equivalent to a return trip from Mosgiel to Dunedin in a petrol-driven car.[9] All these graphs and numbers can be hard to take in. Rather than making it a scientific issue around carbon dioxide, we can get to the nub of the story by saying "ice is cool." Conversely, we could say that CO_2 is not cool. When CO_2 emissions warm things up, ice is no longer a solid and becomes water. More water flowing into the oceans takes up more space and sea levels rise. For this reason, an iceberg shape was chosen as the 3D shape of our visual indicator – a constant reminder of what is at stake.[10]

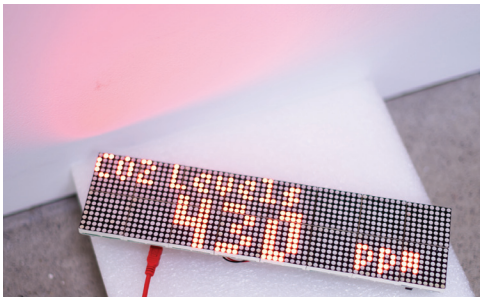

Figure 3 previous page. Pam McKinlay (weaving and photograph) and Henry Greenslade (electronics), Farewell – Tasman Glacier, 2019, hand-woven fine wool khata, electronics. From the Ice is Cool series.
Figure 4. Detail electronics. Photographs: Pam Mckinlay.

We exhibited the electronic components of the CO_2 sensor as part of a Climate Change installation from the *Ice is Cool* series[11] in "The Complete Entanglement of Everything" exhibition in September 2020.[12]

"Transitional arts practice proposes how 'macro' challenges can be transformed creatively by a daily 'micro' personal practice."[13] We hope that our learnings about awareness of our immediate environments will embed themselves in small, personal actions and translate to wider actions aimed at curbing human-induced CO_2 concentrations in the outer environment. We hope the the Iceberg sensor will encourage adaptive behaviour change in room occupants. When people take action to improve their immediate air quality, we hope to trigger thought and action about the broader implications of CO_2 emissions outside the room itself. While we can open windows and doors in a building to improve our immediate comfort levels, we all live in an open room when it comes to our planet. Carl Sagan is quoted as saying that "air does not carry a passport."[14]

DATA AND THE DEVICES

Both the LED and Iceberg sensor devices can be powered by regular phone chargers and have the capacity to log data when plugged into a computer. Early test data from both the Iceberg device and LED panel revealed that room levels of CO_2 were frequently above 2000 ppm (parts per million). Testing during the Covid-19 lockdown revealed that outside a bedroom window in Mornington, Dunedin, CO_2 levels were a resting 419 ppm. Keeping in mind that 350 ppm of carbon dioxide has been identified as the safe upper limit to avoid a climate tipping point, we found this result very revealing and rather disturbing. It brought the international readings right into our urban backyards. Global monitoring by the National Oceanic and Atmospheric Administration (NOAA) at the Earth System Research Laboratories on Mauna Loa, Hawaii, confirm that international levels are frequently above 415 ppm.[15] These figures are published every week in the UK *Guardian*'s weekly newsletter, "Green Light."[16]

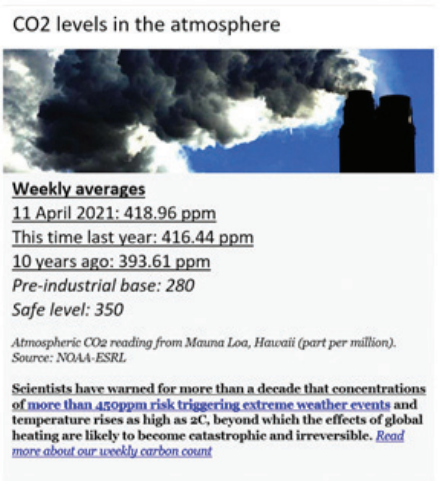

Figure 5 . Screengrab from the *Guardian*'s newsletter "Green Light," which is emailed free each week.

After lockdown and back in the classroom, we found that room-level peaks were also well above satisfactory, and the experiment which had started as an art project took on a new impetus as a student health and wellbeing project.

In rooms, CO_2 concentrations naturally fluctuate over the day depending on occupancy numbers, activities and time of year. In its *Designing Quality Learning Spaces Report*, the Ministry of Education outlines requirements for indoor air quality and thermal comfort:

> Indoor air quality and thermal comfort have a direct impact on the usability of the space and on learning outcomes. … Indoor air quality is dependent on the concentrations of CO_2 and other respiration derived pollutants, volatile organic compounds (VOC), particulate matter and other pollutants such as formaldehyde … Occupied learning spaces are expected to have adequate ventilation and to provide a minimum indoor air quality range of 1000-1500 ppm CO_2 (or less) over the course of the school day [and] indoor air temperatures within occupied learning spaces are expected to be within a range of 18°C to 25°C for the majority of the year.[17]

CO_2 is recognised as a useful proxy for outdoor and indoor airborne pollutants. Indoors, it also serves as a proxy for airborne respiratory pathogens which would otherwise be invisible. This has become more topical in a Covid-19 world. Our aim to create a visual indicator that would alert room occupants to their internal air quality and encourage them to take responsibility for increasing ventilation and air movement, has been succesful.

The Iceberg device debuted at the "Mapping the Anthropocene in Ōtepoti/Dunedin: Climate Change, Community and Research in the Creative Arts" symposium, sponsored by Otago Polytechnic.[18] As the image on the left in Figure 6 shows, by morning tea time of the first session, the iceberg was already glowing an angry red. Although for the remainder of the symposium readings fluctuated, our experimental cohort took responsibility for keeping the iceberg a cool green (see photo on the right from the closing of the symposium in Figure 6).

Figure 6. Speakers at the "Mapping the Anthropocene in Ōtepoti/Dunedin" symposium.
Bridie Lonie (first day, 10 am); Ron Bull (second day, 3 pm).

WHAT'S INSIDE THE BOX?

The technical components were created as a special student project by Henry Greenslade from the Information Technology Department, Otago Polytechnic. As part of his project, Henry documented the process with technical drawings, photographs, diagrams and Readme.md documents so that variations of the device could be made fairly easily in the future. Full technical information for this project, including Readme.md texts, are available at GitHub.[19]

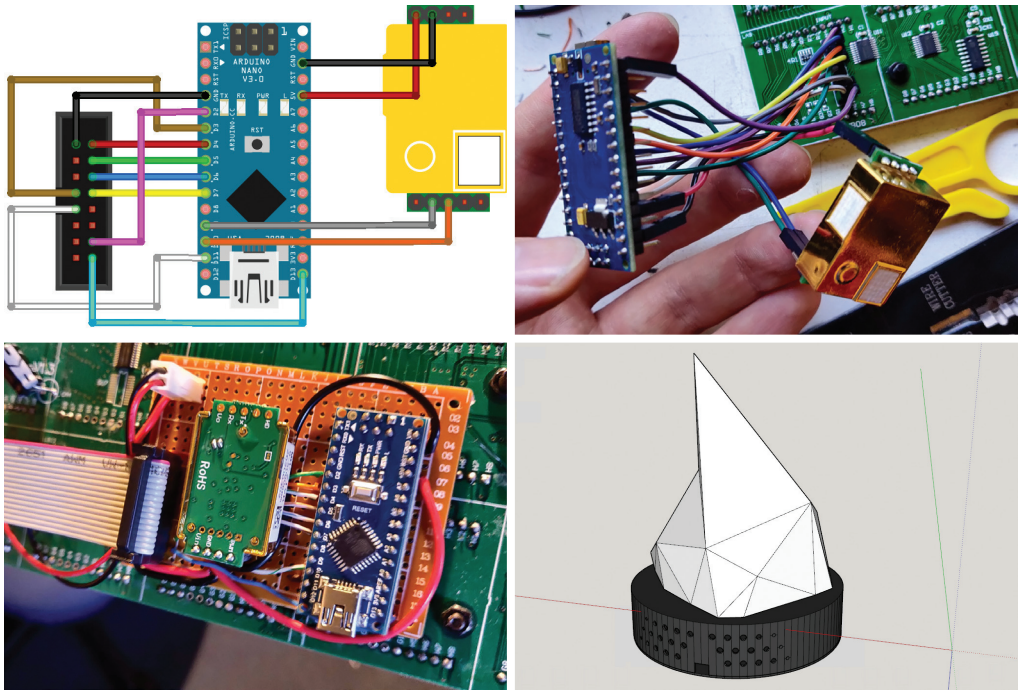

Figure 7. "Collection of device sketches, 3D models and other bits & bobs for special topic" – GreensladeNZ/specialproject at GitHub (https://github.com/GreensladeNZ/specialproject).

RISING WATERS – EMERGENT SEAS

Rising waters are literally and metaphorically threatening our "islands of identity." Keeping with the sensors and monitoring work, and thinking about the effects of CO_2 on the cryosphere, we added a 'rising seas' scenario to the artworks displayed in the "Earth: Caught in Stone" Art+Science exhibition held in the Dunedin Community Gallery from 15-22 May 2021.[20]

As part of the Art+Earth (Art+Science) Project,[21] I worked with GNS Science cartographer Belinda Smith Lyttle. We considered what Antarctica might look like above RCP 2.6, minus part of its ice sheet, and the idea behind *Emergen(t) Seas* came about. This warranted a new LED panel, which went through various iterations of text and design changes, starting with:

EMERGENT
SEA

EMERGE
in sea

We finally settled on a play on words, with E / MER / GEN / SEA as in "emergency." At the exhibition, a gallery visitor also pointed out that "mer" also means "sea" in French.

This exhibit was completed as part of a light box triptych for the Art+Science Exhibition 2021. The centre-placed *Emergen(t) Seas* light box referred back to the traffic light system colourway of the original CO_2 sensor panel and iceberg device. The cover piece of the light box was a map of future Antarctica showing the continent with ice stripped back and revealing the bedrock of the Antarctic Plateau and submarine relief of the bathymetry of the Antarctic and adjoining continents Australia and Zealandia, all laser etched in "Ice Perspex."

With some of its ice covering stripped off, we could see how Antarctica might appear as a continent surrounded by a chain of outer islands. Beyond the outer Antarctic archipelago, we caught glimpses of the major rifts in the bathymetry of the sea floor and could track these towards the partly submerged continent of Zealandia and neighbouring Australia – all of which once made up the mighty continent of Gondwanaland. While the land mass of Antarctica was still largely recognisable, the disintegration of the shoreline of Aotearoa New Zealand was intended to give pause for thought about our future buoyancy as a country, with freshly melted waters from the southern sleeping giant lapping at our doorsteps.

Figure 8. Final LED arrangement for E / MER / GEN / SEA, part of the *Emergen(t) Seas* exhibit.

Adjoining the LED box were two underlit tapestries, which were woven responses to the landscapes around the Taylor Mountains inspired by photos from the GNS Antarctic Survey of Southern Victoria Land, Antarctica. As a tapestry weaver, this is how I draw (with thread). The white-on-white tapestry was an interpretation of the fields of snow and ice in the glacier sheets (up to 5 km thick) that flow and cascade around and over mountains from the Antarctic Plateau to the Southern Ocean. Each of the darker, backlit 'slubs' represents a buried mountain, sometimes a volcano and, closer to the ice-shelves, whole islands which have been completely captured in ice for millennia. The second, more figurative piece was an interpretation of Finger Mountain, an exposed escarpment of the Ferrar Dolerite and Beacon Supergroup in the Transantarctic Mountain range. It is a spectacularly dramatic feature in this part of the world, which I personally find awe-inspiring; its presence raises questions as to what it is and why it's there.

ART AND SCIENCE – MAKING ART AS IF THE WORLD MATTERS

We are daily being asked to make changes to mitigate and adapt to a myriad of long-term changes from global warming that are starting to be visited upon us. According to Dan Miller of the clean-tech Roda Group, Berkeley, we need to more fully understand our approach to threat indicators and evolve a better response to the climate change crisis. As a species, we are programmed to react to visible (and audible) threats. If it's out of sight, it's out of mind and not perceived as an immediate personal threat. It's a kind of evolutionary mental blind spot or aporia ("not seeing"). There is, as Miller puts it, "no lion at the door." There is no single enemy – climate change is complex, it is unpredictable and non-linear and WE are all the cause or enemy. It is WE who constitute the threat and WE who need to act. In the pieces described above, we created works to stimulate thinking about acting locally, but thinking globally.

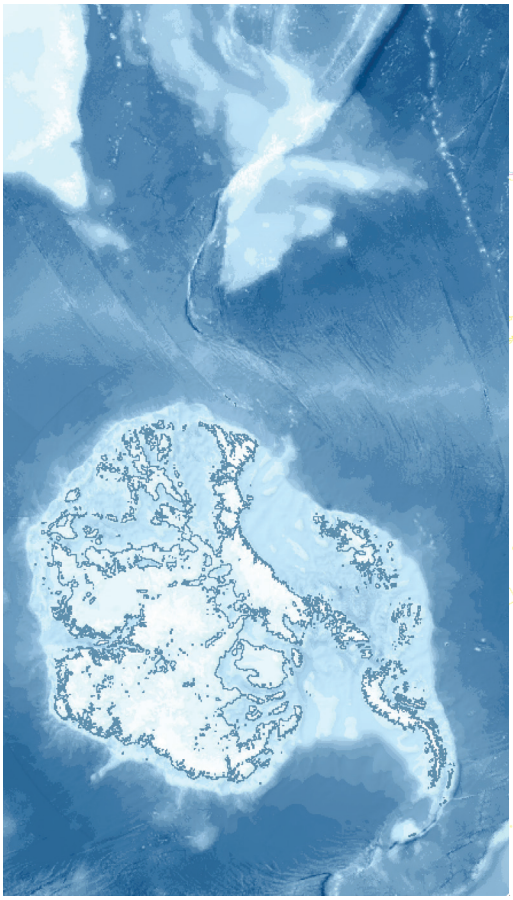

Figure 9. Map of the Southern Ocean. Compiled image, south of 60 degrees, showing Antarctic basement, proximity of Antarctica to NZ and Australia.
The image is stitched from data obtained from the British Oceanographic Data Centre and the GNS Antarctic Survey (Belinda Smith Lyttle).

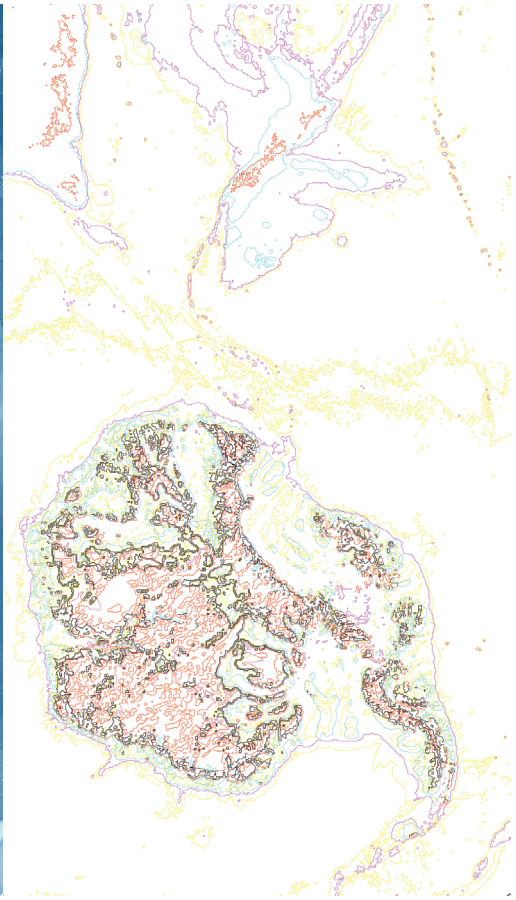

Figure 10. Early-stage file for etching on perspex (Pam McKinlay).

In *Playing for Time: Making Art as if the World Mattered* (edited by Lucy Neal, 2015),[22] artists share their visions of how concepts of art and activism are merging around the climate crisis. We know what must be done and we find communities to share our practice, such as the Art+Science series. We take our thoughts and spirit forward in our works and connect to the public with our exhibitions and the participatory public programmes that run alongside our exhibitions. The artworks stimulate discussion and help visitors make a connection between the newly presented knowledge and actions they can take out of the gallery and into their lives.

The next nine years will constitute the crucial window of consciousness in deciding which RCP scenario pathway will be the most likely outcome. CO_2 does not have a voting agenda, nor does it have an agenda on a just transition. All of our futures depend on turning these carbon emission trajectories around. Amid all the sociopolitical side-show activity involved in decision-making, we cannot afford, in Kim Stanley Robinson's prescient phrase, to be *Homo sapiens oblivious*.[23]

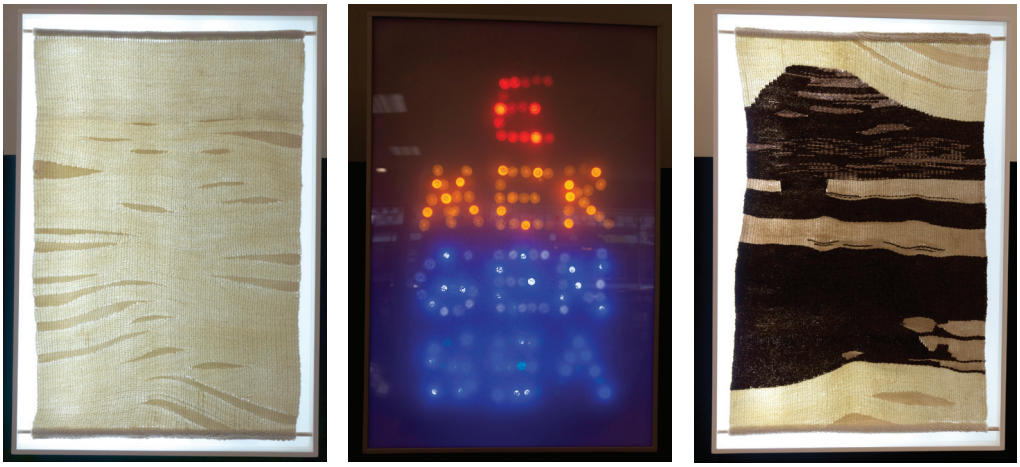

Figure 11. Down the Rabbit Hole Art Collective (Pam McKinlay, Henry Greenslade, Leonora DaVinci) with Belinda Smith-Lyttle (scientist), *Emergen(t) Seas – The Bedrock of Antarctica*, 2021, triptych, light boxes, 680 x 1016 mm.

Co-makers in this work were: Pam McKinlay (weaving and laser etching) Henry Greenslade (electronics), Belinda Smith Lyttle (cartography) and Leonora DaVinci (joinery).

Acknowledgements also go to Adon Mossal, Nevill Atuon, Ken Wyber, Keir Russell from Critter Design and Hannah Joynt.

Pam McKinlay (ORCID ID: https://orcid.org/0000-0002-1731-6437) is a writer and an artist with a background in applied science and the history of art. She is a convenor of the Art+Science Project series at Dunedin School of Art. As an artist, she works in collaboration with other artists and scientists locally and nationally in community outreach and education projects on the themes of climate change, energy, the cryosphere and ocean acidification.

1 EPICentre is a multidisciplinary workshop studio at the Otago Polytechnic.

2 RCP (Representative Concentration Pathways) are greenhouse gas concentration scenarios used for climate modelling. Their primary purpose is to provide time-dependent projections of atmospheric greenhouse gas (GHG) concentrations.

3 "IPCC, 2013: Summary for Policymakers," in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, eds TF Stocker et al. (Cambridge, UK, and New York: Cambridge University Press, 2014), 23 (Table SPM.2 | Projected change in global mean surface air temperature and global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005), http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf.

4 Steve Graham of NASA observatory quotes Tyndall in a historical profile, "John Tyndall (1820–1893)," 8 October 1999, *Earth Observatory*, NASA, https://earthobservatory.nasa.gov/features/Tyndall.

5 JA Church et al., "Sea Level Change," in Stocker et al., *Climate Change 2013*, 1187, https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf.

6 Ibid.

7 Yale Climate Connections, *Meltwater Pulse 2B*, 2014, https://www.youtube.com/watch?v=7119lzLsBRc&list=UUtZdUYUZr493AUh_ElnBYxQ&index=11.

8 Ruth Mottram, "The Melting of Greenland's Ice Sheet," Saturday Morning, *RNZ*, 31 August 2019, audio, https://www.rnz.co.nz/national/ programmes/saturday/audio/2018711238/ruth-mottram-the-melting-of-greenland-s-ice-sheet.

9 Environment and Energy Management Agency, *CO_2 Information for Transport Services: Application of Article L. 1431-3 of the French Transport Code: Methodological Guide*, https://thepep.unece.org/sites/default/files/2017-06/Info_CO_2_Methodological_Guide.pdf. Variable factors depend on type of vehicle, fuel type, load and topography.

10 Tyrdle, "Crystal Iceberg," 14 March 2017, https://www.thingiverse.com/thing:2174030. Crystal Iceberg by Tyrdle is licensed under the Creative Commons – Attribution – Non-Commercial license.

11 "The Complete Entanglement of Everything" exhibition, 28 September-2 October 2020, Dunedin School of Art, Dunedin, New Zealand. The exhibition was held in association with the symposium, "Mapping the Anthropocene in Ōtepoti/Dunedin: Climate Change, Community & Research in the Creative Arts," 26-27 September 2020. Photo documentation of the exhibition by Jodie Gibson. See https://www.flickr.com/photos/dunedin_school_of_art/50515001912/in/album-72157716560772858/.

12 For "The Complete Entanglement of Everything" exhibition catalogue, see https://issuu.com/dunedinschoolofart/docs/the_complete_entanglement_of_everything_exhibition.

13 Lucy Neal, ed. *Playing For Time: Making Art as if the World Mattered*, (London: Oberon Books, 2015), 14.

14 Matt Stieb, "Neil deGrasse Tyson Takes us Out of This World," *San Antonio Current*, 10 June 2015, https://www.sacurrent.com/sanantonio/neil-degrasse-tyson-takes-us-out-of-this-world/Content?oid=2445563. Neil deGrasse Tyson quoting Carl Sagan.

15 NOAA, Earth System Research Laboratories – Global Monitoring Laboratory, "Trends in Atmospheric Carbon Dioxide," https://www.esrl.noaa.gov/gmd/ccgg/trends/. The graphs show monthly mean carbon dioxide measured at Mauna Loa Observatory, Hawaii. The carbon dioxide data on Mauna Loa constitute the longest record of direct measurements of CO_2 in the atmosphere.

16 "Green Light", *The Guardian*, https://www.theguardian.com/environment/series/green-light.

17 Ministry of Education Te Tāhuhu o te Mātauranga, *Designing Quality Learning Spaces: Indoor Air Quality and Thermal Comfort*, Version 1.0, September 2017, https://www.education.govt.nz/assets/Documents/Primary-Secondary/Property/Design/Flexible-learning-spaces/DQLSIndoorAirQualityThermalComfortV1-0.pdf,

18 Otago Polytechnic, "Mapping the Anthropocene in Ōtepoti/Dunedin: Climate Change, Community and Research in the Creative Arts," https://www.op.ac.nz/study/creative/art/research/symposia/tile?id=4412.

19 GreensladeNZ, *Github*, https://github.com/GreensladeNZ/specialproject.

20 "Earth: Caught in Stone" exhibition, Dunedin Community Gallery, 15-22 May 2021. For the exhibition catalogue, see https://issuu.com/dunedinschoolofart/docs/art_earth_catalogue_hq_complete.

21 The Art+Science Project was initiated by Peter Stupples (Dunedin School of Art) and Ruth Napper (University of Otago) in 2013. Utilising an annual theme, artists and scientists from specific disciplines are brought together, encouraged to share their ideas and experience and produce an exhibition based on those collaborations. The artworks which result are inspired by their mutual interaction. Not all artists and scientists agree on where to draw the defining lines around collaboration, and no two partnerships are alike. They range from artists and scientists both working on the artwork, at one extreme, to the typical scenario of the artist finding inspiration in some aspect of the research. The last three Art+Science projects have been co-convened by Pam McKinlay.

22 Neal, *Playing For Time*.

23 Kim Stanley Robinson, *New York 2140* (New York: Orbit, 2017), 377.