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PAM MCKINLAY WITH GEOFF WYVILL

Ice Is Cool – Artist's response to John Tyndall, "Ice Flowers"

INTRODUCTION

Ice at the Margins was a series of woven panels made in response to "The Forms of Water in Clouds and Rivers, Ice and Glaciers", written by John Tyndall in 1872. Tyndall has been called the "father of climate change" and his work on the properties of gases to absorb and transmit radiant heat led to speculation on how fluctuations in water vapour could be related to climate, and how these gases help to moderate temperature on planet Earth. His book has never been out of print. Noting that a leading international climate research centre is named after him[1], I am interested in the significance of Tyndall's contribution to the history of science, and the continuing effects of greenhouse gases on changes in the cryosphere and impacts on water security. My focus for the Art+Water project was "ice", and my muse was Tyndall's historical "ice-flowers" experiment.[2]

"THE FORMS OF WATER"

Tyndall was an avid mountaineer and ponderer of the forms and motions of glaciers. The immense body that is a glacier is underpinned by the minutiae of the individual ice crystals from which it is made. Tyndall's "The Forms of water" considered the water cycle from the creation of ice (the freezing or deposition of water vapour at high altitude), to glacial action (ice on ice and ice on rock), melting (on the surface, within, and beneath the ice mass), egress along river journeys from mountain to the ocean, and return as "water dust" in clouds travelling on high altitude winds. Tyndall recognised that glaciers are part of an integrated climate system, part of the water energy cycle and linked to clouds and atmosphere (ice, water, vapour).

Towards the end of the nineteenth century physicists, James Clerk Maxwell and Josiah Willard Gibbs, described the relationship between solid, liquid, and vapour, in a model of an imaginary liquid that was based on water, and visualised the states of phase transition.[4] Their thermodynamic model expressed the interconnection (in a closed system) between five state variables: energy, volume, entropy, temperature, and pressure.[5]

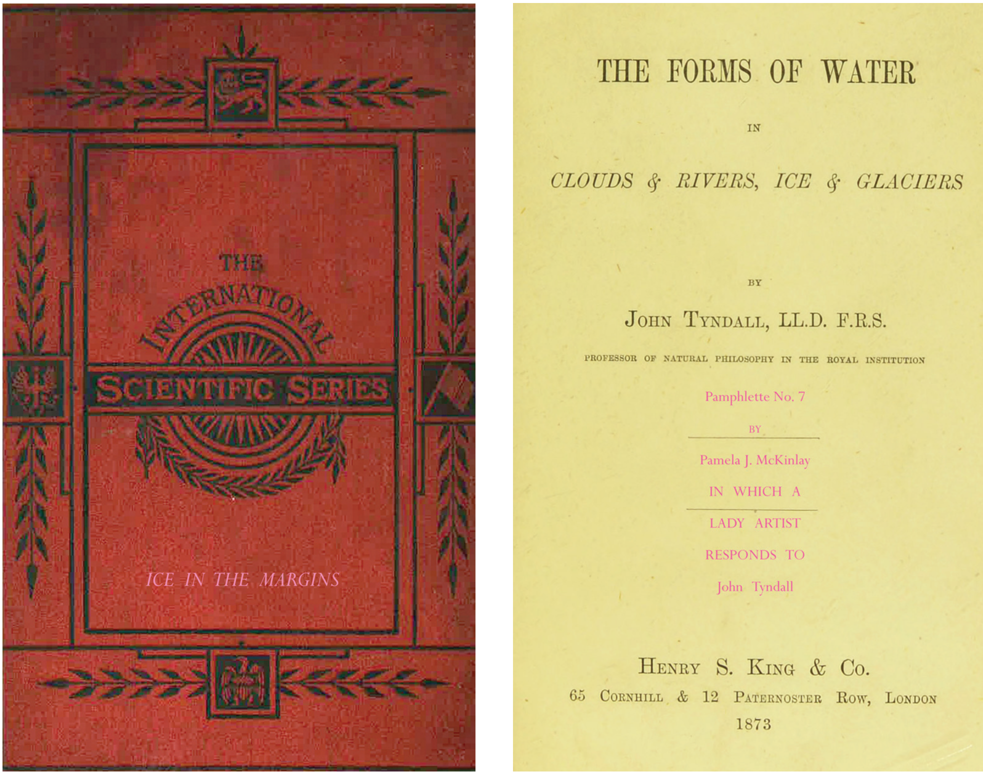


Figure 1. Pam Phlaterre[3], *Ice is Cool*, pages 1–2 Pamphlette No. 6, 2019, based on the original *"The Forms of Water"* over-printed in pink. Printed on indigo digital press on mohawk paper, 15 x 21 cm.

In Chinese philosophy, the vital principal linking life and earth systems is the relationship between energy and water, described as feng shui, which translates as "wind-water".[6] In Te Ao Māori, the underlying essence or lifeforce is described as "mauri." As Tina Ngata puts it:

> Mauri is the underpinning energy that manifests as tangible and or intangible representations of form. When mauri is disrupted or thrown out of balance, our ecosystems dynamically shift to realign stressors and find a new point of equilibrium or stasis...purity of water flowing through catchments is the measure of mauri and all its energetic manifestations as wai.[7]

Tyndal's research is significant for looking at the properties of the "invisible" effects on water/energy in integrated climate systems. He noted that the perfectly colorless and invisible gases and vapours had varying abilities to trap and transmit radiant heat in the atmosphere. In fact, he observed that, of all the components of the atmosphere, water vapour is the strongest absorber of radiant heat. As such, it is the most important gas controlling Earth's surface temperature. Without it, the Earth's surface would be, as Tyndal put it, "held fast in the iron grip of frost".[8] However, he also concluded that, because water vapour (along with carbon dioxide and methane) strongly absorbs thermal infrared radiation, fluctuations in them could drive climate change.

RECIPE FOR A GLACIER:
MAKE SNOW, FREEZE AND COMPRESS FOR MILLENNIA.

Figure 2. Snow making at Coronet Peak.

0 degrees Celsius is calibrated to be the melting point of ice and is also the temperature we associate as freezing point.[9] Water molecules need fine particulates, such as dust or pollen, on which to get aligned and start crystallising (a process called nucleation).[10] The rate of cooling, and other factors, determine the shape of the resulting ice crystals. Understanding this process is the basis of the multimillion snowmaking business. The technology underpins the viability of ski resorts when demand for snow outstrips natural snow fall, or to supplement quantities when natural snowfall occurs out of sync with holidaymakers. Those versed in the art of snowmaking, follow a basic recipe of combining tiny water droplets at high altitude with a little help from "mother nature". Air temperature, size of the water droplets, and humidity (wet-bulb factors) determine the quality of the snow/ice crystals in the final snow product. Mountains further from the sea have drier air and better snowmaking possibilities.[11] Snow is one thing, but alas, we can't make a glacier. Glaciers exist in polar regions and on high altitude mountains. The scale of natural snowmaking, and deep time accretion of tens of thousands of years of snow fall, is beyond the technology of pipes and fans blasting into the freezing air to make a slope of white frozen powder.

THE SHAPE OF ICE

Tyndal's "Ice Flower" experiments reveal the crystallography of pond ice. Of note, the word crystallography is derived from the Greek "crystallon" (meaning "frozen drop"), and so also has an ice connection. During the Art+Science project, our attempts to produce ice flowers were thwarted by a lack of ice in our antipodean summer. Experiments to create ice using modern equipment to freeze and melt (e.g. by laser) also demonstrated ice made in a freezer differs in form from that found in nature, such as in Tyndall's pond ice. Not only is ice cool, the ice crystals we were looking for are difficult to make and control.

We were, however, able to find a re-creation of Tyndal's experiments (by the Royal Institute in 1931), and see how ice crystals are formed by observing the reversed process under magnification during melting. The pond ice experiment revealed an array of crystalline structures with hexagonal symmetry $I_{(h)}$. As described by the Royal Institute:

> "The crystalline forms which built up the block during freezing, become evident as the process is reversed; the absorbed heat breaking down the structure, crystal by crystal, leaving water in the shape of the separate melting crystals. Ice floats on water, so when an ice crystal melts, the water it forms as the ice flower grows occupies a smaller space, leaving a little bubble, which can be seen growing and moving about in each 'flower' as it spreads out."[12]

A small proportion of experimental ice formed in laboratory conditions $I_{(c)}$ has a diamond structure (sometimes called cubic ice). Cubic ice forms naturally in the upper atmosphere from very fine water droplets and high altitude atmospheric pressure. Although difficult to prepare in a laboratory, it is thought that this is the first stage of ice crystal nucleation at high altitude, which later metastasizes to the hexagonal form. Within high clouds, the solid forms of water include a crystalline mix of cubic ice and "stacking disordered ice" (or stacking-faulted hexagonal ice, $I_{(h)}$).[13] For the first of my weaving responses, I used a cubic "flower" form to express the ice found at high altitude in the Himalayas.

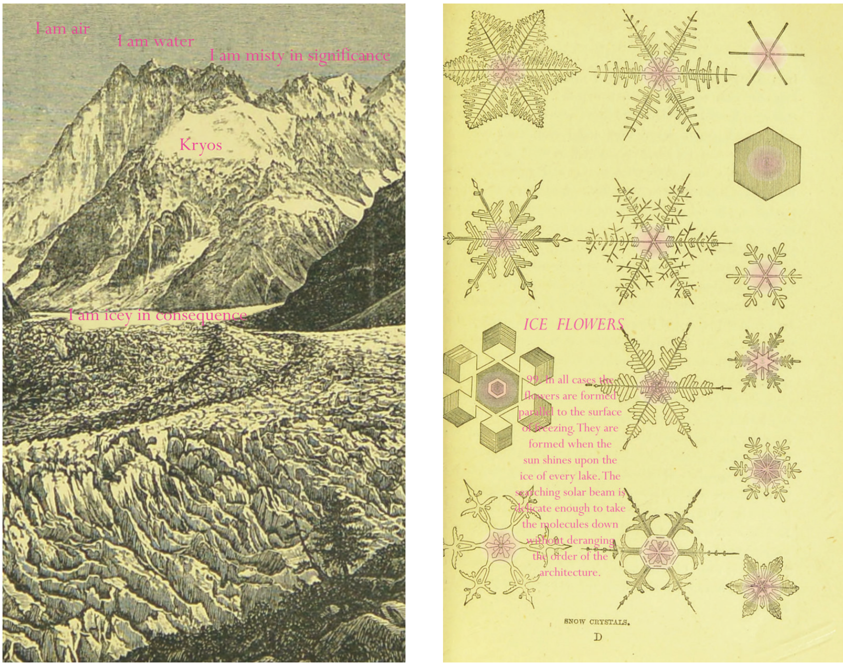


Figure 3. Pam Phlaterre, *Ice is Cool*, page 3–4 Pamphlette No. 6, 2019, based on the original *"The Forms of Water"* over-printed in pink. Printed on indigo digital press on mohawk paper, 15 x 21 cm.

FROZEN, SNOW WHITE AND ICE BLUE

The colour palette in my final series picked up on the changing colours of glacial ice, from depth to surface to meltwater. While snow is white, and the surface of the glacier is white (unless it is carrying rock debris), meltwater/streams on the glacial surface and freshly calved icebergs range from blue to turquoise, and later become white – what's happening here? The crystalline structure in icebergs, compacted under immense pressure over thousands of years, eliminates the air that was originally trapped in the fallen snow. With little air or internal reflective surfaces, the ice absorbs sunlight in all the longer wavelengths, and scatters light in the short or blue frequencies due to Rayleigh scattering. As the surface of the ice melts, it changes and so does its absorption/reflection capacity, and the ice appears white as all the colours are reflected. Melt water flowing into terminal lakes gets its colour from "rock flour". This fine sediment, suspended in the water, gives a milky appearance. The absorption and scattering effect in the short range give it the appearance of being in the turquoise-to-blue spectrum.[14]

Figure 4. Grounded icebergs at the outfall river of Tasman Lake, July, 2019.
Inkjet on hotpress, 45cm x 2.5m. Photograph: Pam McKinlay.

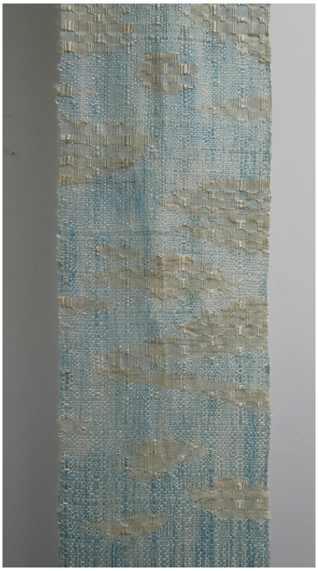
WEAVING ICE IS COOL

Ice is Cool was woven as homage to *khata* (white silk scarves traditionally associated with the Himalayan region and famously gifted to mountaineers such as Ed Hillary). The symbols incorporated into the scarf design were based on repetition of an ice crystal motif in the cubic form, and woven white-on-white using fine wool/silk and highly reflective fine rayon. The surface shimmers along the length of the piece, and the change in pattern at intervals indicate the massive forces and underlying topography that determine rates of flow in these high altitude glaciers. Hand-weaving the piece with such fine yarn also meant progress was made at a glacial pace!

The story continued in *Ice at the Margins I (2019).* Surface changes on the woven glacier panel included melt streams (dyed using an ikat technique), which ran most of the length of the weaving toward the "glacier face," where the structure of the weave rapidly began to disintegrate with icebergs floating off the bottom of the panel. *Ice at the Margins II (2020)* picked up this theme, with greater disintegration evident and the weaving becoming more "watery". The woven panels employed multiple patterns per line to create a more changeable surface, mirroring the increased energy changes and shift in forces acting in and across the ice. A sense of continuity across the three panels was evoked by use of the recurring abstract ice motif in the diamond (cubic) pattern with the implied reminder that every glacier begins its journey as a snowflake.

A final piece was woven in homage to Okjökull (a glacier on Ok Mountain in Iceland). Okjökull has become an international symbol of "once was glacier"; it no longer flows and was declared deceased in 2014. Most of the length of this scarf/panel is the woven rocky debris of the scarred landscape of the moraine, which is all that remains as the ice retreats to a small broken patch of ice at the top of the mountain.





Figures 5-7. Pam McKinlay, *Ice is Cool* and *Ice at the Margins I*, with photo segment, 2019, Art+Water Exhibition; and *Ice at the Margins I*, 2019; and *Ice at the Margins II*, 2020; and detail of *Ice at the Margins II*.

CONCLUSION

The *Ice is Cool* series was a response to historical and contemporary re-enactments of experiments to reveal "ice flowers" in the structure of ice, as well as site visits to glacier terminals. The resulting artwork was a series of narrow, vertical, hand-woven panels and a photo scroll (a section of *Farewell to Tasman Glacier* was exhibited). The surface of the weavings are fine and complex, inviting close inspection, discussion and create potential for a narrative space.[15] John Tyndall's early speculations on how fluctuations in water vapour and carbon dioxide would be causal to changes in the earth's climate are now common knowledge. For every 1 kg of CO2 emitted, 15 kg of ice melts somewhere in the world.[16] What we do on land affects the atmosphere, which in turn affects our ice. Glaciers have become icons of global temperature change as the "canaries in the mine", compared to some of the more intangible impacts forecast from climate change. These changes are, as Helen Meyer Harrison observed, "living in the fast lane if you are a glacier, living in the slow lane if you are a person."[17]

Ice is always and only ever cool.

> I am misty in significance
>
> In sun and air, I am water
>
> Frozen - I am icy in consequence

Ice is Cool, 2019, a living poem, by Pam Phlaterre

Pam McKinlay (ORCID No 0000-0002-1731-6437) has a background in applied science and history of art from the University of Otago. As an artist, she is a maker predominantly in weaving, ceramics, and photography, and works in collaboration with other artists in community outreach and education projects around the theme of climate change, sustainability, and biodiversity.

1. Tyndall Centre, https://www.tyndall.ac.uk/about
2. Royal Institution Archives, "Tyndall's Ice Flowers," a 1930s digitised Cine Kodagraph from the RI film archive. A black and white silent film shows the setting up of an experiment using a magic lantern slide, light source, water tank, and a block of ice. This early teaching film recreates an experiment carried out by John Tyndall at the Royal Institution. https://www.youtube.com/watch?v=gmnmQ3x21q8&list=PLaI2Dq06taLYOSYiC7zf938wHLQpgRCFj
3. Pam Phlaterre is the non de plume of the author.
4. When matter changes from one state to another it is called a phase transition. Examples include: deposition, condensation, vapourisation, freezing, melting and sublimation. The Maxwell and Gibb models didn't include interactions with other gases.
5. SciFox, "Maxwell´s (or rather Gibbs´) Thermodynamic Surface (energy-entropy-volume surface) and pVT Surface," *Physical Chemistry 101 YouTube channel*, https://www.youtube.com/watch?v=Pgxno-9hY1U by Jakob Lauth
6. *Feng shui* was traditionally based on observations of planetary cycles, which influenced survival: changing weather patterns, access to water and sunlight and fertility of the fields. The basis of *feng shui* was thus to work in harmony with the forces of ''wind and water.''
7. Paul Tapsell and Alison Dewes, quoting Tina Ngata in "One World, One Heath – Whenua, Rongoā, Tangata," in Mike Joy, ed., *Mountains to the Sea: Solving New Zealand's Freshwater Crisis* (Bridget Williams Books, Wellington: 2018).
8. Steve Graham of NASA observatory quotes Tyndal in a historical profile, "John Tyndall (1820-1893)," *Earth Observatory, NASA*, (October 8, 1999) https://earthobservatory.nasa.gov/features/Tyndall
9. 0 degrees Kelvin is calibrated to absolute zero (-273 degrees Celsius). The Celsius scale starts at 0 which is freezing point. The kelvin scale uses Celsius as degree increments. One can directly convert from Celsius to kelvin by simply adding 273.15 to the degrees Celsius value. 0 degree Celsius is equivalent to 273 degrees Kelvin which is also the temperature of thermodynamic equilibrium where all three phases of water are present, called triple point.
10. Don Rasmussen, "Ice formation in aqueous systems," *Journal of Microscopy* 128 (2011): 167–174, DOI 10.1111/j.1365-2818.1982.tb00448.x.
11. On the Snow, "Snow Science: Snowmaking, Part 1," https://www.youtube.com/watch?v=3eOiRM1JApg, Making snow on the mountain is determined by wet-bulb factors: air temperature, humidity and pressure. Water drops freeze more quickly when the air is dry.
12. "Tyndall's ice flowers," Cine Kodagraph film from the Bragg Film Archive, 1930s, *The Royal Institution*, https://www.rigb.org/our-history/bragg-film-archive/crystallography/tyndalls-ice-flowers
13. Martin Chaplin, *Water Structure and Science*, London Southbank University, http://www1.lsbu.ac.uk/water/ice1h1c.html (2002, last updated 20 October, 2019). The term "cubic ice" has been historically used for less-than-pure ice crystals (stacking-faulted hexagonal ice or $I_{(h)}$). Using modeling, stacking-disordered ice crystallites at 230 degrees K or Zero^{0} C are shown to be more stable than hexagonal ice crystallites, making their ice nucleation rates possibly more than three orders of magnitude higher than predicted by classical nucleation theory.
14. Eyvind Aas and Jim Bogen, "Colors of glacier water," *Water Resources Research* 24, no. 4 (1988): 561–565, doi:10.1029/WR024i004p00561
15. Pam McKinlay and Terence Scott, "On Caustics: A Conversation", *Junctures: The Journal of Thematic Dialogue*, 16 Light (2015): 68.
16. Ruth Mottramon, "The melting of Greenland's ice sheet," *Saturday Morning*, Radio NZ (31 August 2019) https://www.rnz.co.nz/national/programmes/saturday/audio/2018711238/ruth-mottram-the-melting-of-greenland-s-ice-sheet
17. Bridie Lonie cites Helen Meyer Harrison in "Closer Relations: Art, Climate Change, Interdisciplinarity and the Anthropocene," (Doctor of Philosophy thesis, University of Otago, 2018), 108; (note 224) quote is from Marda Kirn, ed., *Weather Report: Art and Climate Change* (Boulder: Boulder Museum of Contemporary Art in collaboration with EcoArts, Colorado Museum of Contemporary Art, 2007).