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Southern skies: Australian atmospheric research and global climate change

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Abstract

Purpose – The purpose of this paper is to examine the role of Australian climate scientists in advancing the state of knowledge about the causes and mechanisms of climatic change and variability in the Southern Hemisphere during the 1970 and 1980s.

Design/methodology/approach – The paper uses the methods and insights of environmental history and the history of science to analyse archival and published data pertaining to research on atmospheric pollution, the Southern Oscillation and the regional impacts of climate change.

Findings – Australia's geopolitical position, political interests and environmental sensitivities encouraged Australian scientists and policymakers to take a leading role in the Southern Hemisphere in the study of global environmental change.

Originality/value – This article builds on critiques of the ways in which planetary and global knowledge and governance disguise the local and situated scientific and material processes that construct, sustain and configure them.

Keywords Climate change impacts, Climate history, Environmental history, Human geography

Paper type Research paper

Introduction

In early December 1975, delegates gathered at the Australasian Conference on Climate and Climatic Change at Monash University, Australia. There, in the south-eastern suburbs of Melbourne, over two-hundred scientists and researchers from Australia and New Zealand as well as North America and Western Europe gathered at the first conference convened by the Australian Branch of the Royal Meteorological Society. In the conference proceedings, convenor Barrie Pittock explained the urgent need for such a meeting, "Much has been written about Northern Hemisphere climate, sometimes as if it were the global story, but relatively little is available which focusses on the south" (1977, np). The implications of such an oversight were not to be underestimated: "[T]he consequences in terms of a true global understanding of climate are serious. This is of global rather than merely regional concern" (Pittock, 1977, p. 4).

The Southern Hemisphere had long posed challenges to the study of climate owing to the predominance of ocean, rather than land area. Compared to the Northern Hemisphere, its large ocean mass means that few regions south of the equator develop continental climates, and instrumental and palaeoclimatic data are relatively limited as a result (Jones and Allan, 1998). Since the mid-eighteenth century it had been largely accepted that the behaviour of the atmosphere in the Northern Hemisphere could be successfully understood without their

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having to inquire into the workings of the South (Mitchell, 1972). Similarly, climate scientists assumed that due to the dominance of the ocean, the atmospheric circulations of the Southern Hemisphere should resemble "a water-covered globe with a polar ice field" (Taljaard, 1972).

During the 1950s, however, scientists began to gain the means to identify these hemispheric differences and their implications for understanding the workings of the planet's climate systems. The worldwide scientific collaboration initiated under the auspices of the 1957–58 International Geophysical Year (IGY), with its attentions largely focused on the poles, provided the opportunity to collate meteorological data on the Southern Hemisphere. Building on a Southern Hemisphere project underway at MIT, the World Meteorological Organisation (WMO) assigned the task of analysing this data and publishing IGY maps for the hemisphere (20 °S to the South Pole) to the South African Weather Bureau in Pretoria (Taljaard and van Loon, 1964). As one of the researchers involved, Harry van Loon, later recalled in a 2004 interview, "[T]his was before (Apartheid) South Africa was recognised as a skunk among nations" (van Loon, 2004).

By the time the resulting IGY atlases were published in the late 1960s and early 1970s, Australia had assumed the mantle of the "leading meteorological nation of the Southern Hemisphere" (Zillman, 2001). In other areas Australia had already achieved in 1958 something of a "high point for the scientific modernist ambitions of the nation" (Munns, 2010, p. 207), with the opening of nation's first and only nuclear reactor, the federal government's approval of the phytotron and the new round-the-world capabilities of its national airline (Antonello, 2013). Then, in 1966, the city of Melbourne became the site of one of the three World Meteorological Centres of the World Weather Watch, offering a third, Southern Hemisphere counterpart, to Moscow and Washington, DC. This role suggested a continuity of the involvement of active and former meteorologists of the Australian colonies in the International Meteorological Committee in the 1890s, at which they were the sole participants from the Southern Hemisphere (Edwards, 2010). The establishment of a World Meteorological Centre was also consistent with the Australian government's earlier engagement with scientific internationalism as a means to navigate diplomatic tensions regarding Antarctica, which had also centred on Melbourne (Turchetti *et al.*, 2008; Antonello, 2013; Zillman, 2002). From this position, Australian climate researchers built themselves an international reputation in atmospheric matters relating to the Southern Hemisphere and the globe.

This paper examines the role of Australian climate scientists in contributing to global knowledge about the causes and mechanisms of climatic change and variability in the Southern Hemisphere during the Cold War. Drawing on archival sources, scientific publications and the oral and written memoirs of climate scientists, this article contends that both Australia's geopolitical position, political interests and environmental sensitivities encouraged Australian scientists and policymakers to assert a leading role in the study of global environmental change. What follows is an examination of three areas of research in which Australian studies during the 1970 and 1980s undertook to provide local insights into global processes of climate variability and change: atmospheric monitoring; the Southern Oscillation and regional climate impact studies.

Localising atmospheric change

Scientific investigation into the atmospheric and oceanic processes affecting Australian climates has been, not surprisingly given the vast size of the continent, largely an Australian endeavour. The atmospheric-oceanic phenomenon of the El Niño-Southern Oscillation (ENSO) is a key driver of the Australian continent's boom-bust climate, but historical studies of its effects have been largely terrestrially-focused (eg. Flannery, 1994; Garden, 2009; Jones, 2017). Alternatively, environmental historians have turned their attentions southward to the

Southern Ocean and Antarctica, which have long attracted scientific interest, not least for their influence on Australian weather and climates (eg. Griffiths, 2007; Antonello, 2018; McCann, 2018). How Australian climate scientists sought to negotiate, and contribute to, international scientific and political networks of climate research, particularly during the Cold War, remains relatively unexplored.

In historical studies of the ice, the ocean and the atmosphere, vertical and temporal perspectives offer opportunities to revise earlier notions of these spaces as flat, static and timeless. Attending to these physical entities as fluid and dynamic three-dimensional bodies encourages closer attention to the ways in which humans (and others) have experienced and understood these spaces, either separately or as interconnected systems (eg. Griffiths, 2007; Oreskes, 2014; Steinberg and Peters, 2015; Antonello and Carey, 2017; Morgan, 2020a). The very interconnectedness of oceanic and atmospheric processes prompted international scientific collaboration and data collection across vast geographical areas from the nineteenth century. As Rozwadowski (2002, 2005), Hamblin (2005) and Cushman (2013) have shown, the study of such phenomena has historically warranted transnational efforts that cross cultural, political and scientific borders. These endeavours later benefitted from the geopolitical ambitions of the Cold War era, which produced the "knowledge infrastructure" that made these physical processes comprehensible (Edwards, 2010). But the motivations for their study were also rooted in local concerns – after all, the manifestation of such phenomena is experienced at the local level, and researchers undertake their studies in local contexts.

This article undertakes a historical study of Australian climate science and its contribution to global understandings of planetary change in the twentieth century. Extant studies (eg. Weart, 2008; Howe, 2016), focus almost exclusively on the work of scientists and scientific bodies in the United States. Preoccupied with a "trans-Atlantic gaze" (Robin, 2017, p. 62), such works tend to overlook the ways in which climate researchers in other geopolitical and cultural contexts contributed to (and contested) this scientific research and how their material environments shaped their own endeavours. Indeed, the "globalism" of climate science is under growing scrutiny (e.g. Miguel *et al.*, 2019). Ethnographic approaches to the study of climate research communities in Brazil (Lahsen, 2004) and India (Mahony, 2014) have offered crucial insights into the ways in which researchers in the Global South have more recently experienced and interpreted the processes of global climate scientific production. Among informants, they identified a deep mistrust of the perceived Northern framings of "globalist" spaces such as the Intergovernmental Panel on Climate Change and shed light on the ways that non-Northern scientists and policymakers sought to overcome their disadvantage.

Building on these findings, this article offers historical insight into how such tensions between the global and the local found expression in the research agendas of Australian climate scientists working far (at least physically) from Northern centres of calculation in the 1970 and 1980s. Historians have long recognised the cultural and political import of Australia's exterior and interior tyrannies of distance as a geographically vast, white settler nation of the British Commonwealth in the Indo-Pacific region (e.g. Blainey, 1968; Lake and Reynolds, 2008). By the early 1980s, as a former bureaucrat explained, Australia was a "small energy-rich, food-rich and financially-rich country" in an "energy-poor, food-poor and financially-poor region" (Harris, 1982, p. 35). An historical consideration of the Australian experience of the scalar projects of climate knowledge production finds traces of the nation-continent's geopolitical sensitivities during this period, which were (and remain) largely predicated on a sense of exceptionalism and isolation that scientific internationalism might overcome, or at least ameliorate (see, Munns, 2010).

Excavating the ways in which countries such as Australia engaged in global climate scientific production and governance contributes to the wider project of bringing to light the "infrastructural geopolitics" that belie the "infrastructural globalism" of international scientific cooperation (Miguel *et al.*, 2019; Edwards, 2010). This approach recognises the geopolitical asymmetries inherent in global climate science and attends to the deeper historical contexts that configure and mediate the ways in which globalist knowledge is interpreted and applied locally (Mahony, 2014). In doing so, this article seeks not to contest or undermine the findings of climate science, but rather engages with the ways that the historical study of the geopolitics of knowledge can contribute to enhancing climate change adaptation (Adamson *et al.*, 2018). Adamson *et al.* (2018) call for greater historical scrutiny of the present-day scientific concepts and structures that order the global climate politics and climate change adaptation research. Second-order observation, or "observing the observers", they argue, focuses historical analysis on the research itself to identify, account for and critique the distribution of power and agency, in order to stem the perpetuation of the "colonial 'geopolitics of knowledge'" (ibid, p. 201).

As this article shows, Australian climate scientists and policymakers were well-attuned to the Cold War geopolitics of climate knowledge and leveraged their geopolitical position to ensure not only Australia's active participation, but also that Australia's own interests would be best-served by the scientific and political infrastructures under construction. At the international level, the results of these manoeuvres were mixed. Although the first case study traces Australian successful efforts to establish an atmospheric monitoring station for the Southern Hemisphere on Australian soil, the second finds local attempts to understand the El Nino-Southern Oscillation remained peripheral to global climate knowledge production into the 1980s. The final study examines the ways in which Australian climate researchers put global climate science to work in local contexts, while the Australian government negotiated the emerging climate governance regime of the late 1980s. Exploring the activities of these Australian "transnational locals" (Lahsen, 2004) sheds lights on the ways in which global knowledge and governance disguise the local and situated processes that have historically constructed, sustained, contested and configured them.

The southern atmosphere

Following reports in North America that the oxides of nitrogen emitted from aircraft could destroy ozone, a committee of the Australian Academy of Science (AAS) formed to address local concerns, particularly regarding the atmospheric impact of supersonic aircraft (AAS, 1972). The committee recommended emissions from such aircraft should be minimised, and that a stratospheric monitoring program should be introduced. As few of these kinds of aircraft flew in the Southern Hemisphere, the atmosphere south of the equator could be compared with the north to reveal the effects of such pollution. Chairing this committee was Bill Priestley, the head of the Division of Atmospheric Physics, in the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Priestley had overseen the establishment of a regular measurement program of total ozone in 1954, the first in the Southern Hemisphere. Back then, as he would later recall, "the motions in the upper atmosphere and their interactions with the weather and climate were little known anywhere, and the entire Southern Hemisphere was virtually an open field" (1972, p. 13).

In June 1972, Priestley attended the United Nations Conference on the Human Environment in Stockholm, Sweden. With the federal Liberal government only having recently issued its statement on environmental policy, the conference presented an opportunity for Australia to position itself as a key player in the emerging framework of global environmental governance (Boardman, 1990; Robin and Day, 2017). Australian efforts to negotiate a more central role appealed to its geography and degree of economic (and political) development. As the leader of the Australian delegation, the Commonwealth Minister for the Environment, Aborigines and the Arts, Peter Howson declared to the conference, "Australia's environmental problems are not as acute as those of some other countries. We do not have the pressures of population on resources which have contributed to environmental problems in some countries. Our geographic isolation as an island continent makes us less affected by pollution across frontiers from other countries" (Government of Australia, 1972).

The Stockholm conference had called for member nations to commit to establishing atmospheric monitoring programmes to extend knowledge of the chemical composition of the background atmosphere and to determine whether (and why) that might be changing. On his return to Australia, Priestley joined with Bill Gibbs of the Bureau of Meteorology to advocate for the establishment of a baseline station in Australia. As a developed Commonwealth nation, Australia's potential role was both geographic and political: "Australia is one of the few countries in the Southern Hemisphere which has the opportunity and potential expertise to make a worthwhile contribution to an international research enterprise" (WMO, 1974). An Australian station, far from sources of industrial contamination in the Northern Hemisphere, would provide "a pole-to-pole line through the Pacific", joining the US-monitored stations at Barrow (Alaska), Mauna Loa (Hawaii), American Samoa and the South Pole (Pack, 1974, emphasis in original). These US stations already monitored the easterly trade wind belt – an Australian station could monitor the temperate westerlies. Priestley and Gibbs concluded that such a station would have to be established in Tasmania, since this is the only Australian location that consistently remains within the westerlies all year round. Although the Commonwealth agreed in principle to their initiative in 1974, it took several years to identify an appropriate location (Pearman *et al.*, 2017).

On the north-western tip of Tasmania, the island state off the continent's southeast coast, CSIRO researchers eventually found an ideal site for their baseline air pollution station. At Cape Grim (40°41S, 144°41E), there were no impediments to establishing a Commonwealth facility; there was road access and electrical power and it was a favourable location for quantifying changes in carbon dioxide and other climatologically important gases in air masses passing over south-eastern Australia (Pearman *et al.*, 2017). There, on a cliff over ninety metres above the Southern Ocean, a laboratory could sample the "roaring forties" that would be representative of the Southern Hemisphere and thus ideal for contributing to knowledge of global trends. Monitoring began there in April 1976 using a NASA caravan (once used for the Apollo space program), which was replaced with a permanent building in 1981.

By the time the CSIRO facility was established, scientists had discerned the destructive impact of chlorofluorocarbons (CFCs) on ozone in the Earth's stratosphere (Pearman *et al.*, 2017). Reducing concentrations of ozone would allow more of the sun's ultraviolet radiation to reach the Earth's surface, while potentially trapping thermal radiation and warming the planet. As a baseline station, Cape Grim monitored the rising concentrations of these aerosol and refrigerant compounds. Already CSIRO scientists could identify that the concentrations were only 5 to 10 per cent lower in the Southern Hemisphere than north of the equator, despite the fact that over 90 per cent of the compounds were released in the Northern Hemisphere (Fraser and Pearman, 1978). A decade after monitoring at Cape Grim began, British scientists identified what became known as the "Antarctic ozone hole" in 1985, which confirmed fears about the impact of CFCs on the stratosphere (Farman *et al.*, 1985). By this time, the negotiations of the Montreal Protocol were well underway, with the Australian government paying close attention to its possible impacts on public health, primary industries and the Antarctic environment (Richardson, 1988).

Many scientists, meanwhile, were debating the causes and consequences of what appeared to be a global cooling trend. Some climatologists in the Northern Hemisphere suggested that the world's climate was progressing towards a new glaciation (Fleming, 1998). With an ever-growing world population and most arable land already under cultivation, the scientific consensus was that any change in the climate, whether warming or cooling, would severely affect the world's food supply. A series of severe climate events in the early 1970s had raised international scientific and political concerns that the Earth's climate was already changing. During 1972, for instance, drought afflicted the Sahel and the Ukraine, and the Indian Monsoon failed, which resulted in crop losses and world shortages of grain. The publication of the Club of Rome's *Limits to Growth* that year had piqued Western anxieties about whether the Earth could sustain the burgeoning global population (Morgan, 2011).

Following the World Food Conference in November 1974, the federal Labour government requested that the AAS investigate the possible effects of climatic change on world and Australian agricultural production (AAS, 1976). In its report, the Committee highlighted the relationship between human settlement patterns, agricultural production and climate variability. The greater use of lands of marginal rainfall would render these populations and their activities increasingly vulnerable to climate variability, regardless of long-term climate change. For Australian conditions at least, the Committee noted, "visions of vastly increased agricultural production are unrealistic". Regardless of climatic change, if this pattern was to continue, warned the Committee, "the effects of climatic variability are likely to become progressively more serious, frequent and damaging" (AAS, 1976, pp. 10, 23, 78).

In the wake of the 1970s oil crises, researchers' and policymakers' attentions turned to the question of future levels of world energy use and alternative fuel sources. An outcome of this research was recognition of the relationship between the increasing use of fossil fuels and increases in the carbon dioxide content of the atmosphere (Pearman, 1980). There had been growing concerns regarding the effects of such increases on the world's climate since at least the 1940s. Although some scientists supported a global cooling hypothesis, scientific research conducted in the United States in the late 1970s found that increasing levels of carbon dioxide created an enhanced greenhouse effect, which induced a warming of surface air temperatures (Fleming, 1998). This warming would be "accompanied by shifts in the geographical distributions of the various climatic elements such as temperature, rainfall, evaporation and soil moisture" (Pittock, 1980).

One of the recommendations of the World Meteorological Organization's Climate Conference in 1979 was the need for further climate research that might "foresee and prevent potential man-made (sic) changes in climate that might be adverse to the well-being of humanity" (WMO, 1979, np). The following year, scientists presented research relevant to the relationship between carbon dioxide and climate in the Australian context at an interdisciplinary symposium held by the AAS in Canberra. (Pearman, 1980). Since the early 1970s, CSIRO scientists had been examining the carbon dioxide exchange between wheat plants and the atmosphere as part of a broader study on the effect of environmental factors on crop growth (Collis, 2002). This research project expanded as international concerns grew about fossil fuel use and the rising concentrations of carbon dioxide in the atmosphere. Although the measurements only started in 1972, the CSIRO team found evidence of a rising trend in carbon dioxide concentrations just a few years later. These trends parallelled those recorded in the Northern Hemisphere, such as those identified by Charles David Keeling at Mauna Loa in Hawai'i since the 1960s (Pearman, 1984).

The Southern Oscillation

The onset of the severe 1982/3 El Niño overshadowed concerns about a changing climate, while ensuring that the weather remained firmly in the minds of the public in Australia and around the world. In the eastern states of Australia, vast tracts of agricultural land were officially declared drought-affected as farm dams were reduced to dusty basins and farmers were forced to hand-feed their stock. With little vegetation to anchor them, the topsoils from these drought-affected areas eroded and were swept into dust storms that enveloped the region. These circumstances conspired to form the ideal conditions for the ferocious Ash Wednesday bushfires that swept through the states of South Australia and Victoria in February 1983 (Whetton, 1997). Overseas, the El Niño event caused droughts across southern and southeast Asia and unseasonal typhoons in French Polynesia (Glantz, 2001).

The global impacts of this El Niño event triggered a major research effort within the international scientific community towards understanding the phenomenon, particularly its origins in the interactions between the ocean and atmosphere. Leading the endeavour in Australia was Neville Nicholls at the Bureau of Meteorology. As seasonal forecasting for primary producers was a desirable skill for the Bureau, Nicholls thought that a better understanding of atmospheric processes might make the prediction of Australian droughts possible (Nicholls, 1985). He would later attribute various features of the Australian climate, particularly its rainfall variability and the large spatial scales of its droughts and wet periods, to this elusive phenomenon, the El Niño–Southern Oscillation (Nicholls, 1988).

A century earlier, colonial meteorologists had identified the existence of a teleconnection to which they attributed the tendency for Indian and Australian droughts to occur at the same time (Grove and Adamson, 2017; Morgan, 2020b). Although this finding went mostly overlooked, several meteorologists subsequently identified other teleconnections, one of which Gilbert Walker named the Southern Oscillation in 1924 and demonstrated its potential for seasonal prediction. Walker understood this relationship to be a "swaying of pressure on a big scale backwards and forwards between the Pacific Ocean and the Indian Ocean," which took place between a cluster of stations in the north and south Pacific and another in the Indian Ocean (Walker, 1923, p. 109).

Featured among the latter group of centres of relatively low pressure was the Australian station at Port Darwin, the remote northern capital of what was then North Australia (Walker and Bliss, 1932; Adamson, 2020). At Darwin was one of the telegraph stations on the route that linked the Australian colonies to London, thanks to the Overland Telegraph Line. An undersea cable connected Darwin to Batavia, Singapore, Penang and beyond. In Australia, meanwhile, retired Commonwealth meteorologist E.T. Quayle suggested atmospheric pressure in Darwin could be used for seasonal prediction in south-eastern Australia. As he declared in a 1929 paper,

> Darwin has come to occupy a position of singular importance in world meteorology, especially with regard to its air pressure records. These have not only proven valuable as aids to forecasting Indian weather, but show striking correlations with the meteorological phenomena of many other areas, chiefly tropical. It therefore seemed reasonable to hope that since our Southern inland rains are mainly of tropical origin, they also would show some relation to Darwin air pressures (Quayle, 1929, p. 160).

To this end, he related observed atmospheric pressures at Darwin with the rainfall that followed over the continent's southeast. Despite regular calls for seasonal forecasting from the nation's farmers and pastoralists in the following decades, Quayle's findings went largely unexplored. So too the work of Gilbert Walker, whose legacy at the time of his death appeared uncertain (Adamson, 2020).

Scant research into these relationships followed over the subsequent decade, but data from the 1957/58 and 1965/66 El Niño events renewed scientific interest in the Southern Oscillation. In Indonesia, Hendrik Berlage Jr, for instance, demonstrated the utility of identifying the monthly pressure differences between two stations, one representative of the Indo-Australasia region and the other of the south-eastern Pacific-South American centre of action, to construct indices of Southern Oscillation behaviour (Berlage, 1957, 1961, 1966; Allan *et al.*, 1996). While Jakarta had featured in Berlage's calculations, Sandy Troup in Australia used the record at Darwin in relation to data from Papeete in Tahiti to establish a simple index of the Southern Oscillation (Troup, 1965). In contrast to Jakarta, where the political unrest of the mid-1960s had disrupted recordkeeping, Darwin provided a continuous record of pressure in the region since the mid-1870s (Trenberth and Shea, 1987; Vickers, 2005). In the eastern Pacific, Papeete, offered data from at least the 1930s and pressure there was almost "exactly out of phase with Darwin", providing an ideal foil to the northern Australian station (Gordon, 1985). By the mid-1970s, scientists were referring to this relationship as the "Troup Index".

During the 1960s, meteorologists had recognised that the Southern Oscillation was related to the temperature of the east equatorial Pacific and associated with El Niño events. Normally, the pressure in the west (Darwin) is lower than that in the east (Tahiti). During El Niño events, however, the opposite conditions prevail. By the mid-1970s, climate scientists Pittock (1975) and Wright (1977) had each shown that the Southern Oscillation was an important control on Australia's climate and its variability. A greater-than-average pressure difference, indicating a strong Southern Oscillation, is related to increases in eastern Australian rainfall the same year. Pittock subsequently showed that both rainfall and temperature fluctuations in Argentina and Chile are related to fluctuations in the Southern Oscillation in the Pacific, concluding in 1980 that "it is time such links in the Southern Hemisphere were more thoroughly explored" (Pittock, 1980a, 1980b, p. 1369).

By the time the major El Niño of 1982 unfolded, there had been some improvements in data collection, and meteorologists had realised that the El Niño was the product of interactions between the atmosphere and the ocean in the tropical Pacific. Although satellites were now providing insights into sea temperatures, the eruption of Mexico's El Chichón disrupted these measurements (Nicholls, 2005). As a result, some climatologists in the Northern Hemisphere were certain that there would not be an El Niño event that year (Grove and Adamson, 2017). But very high atmospheric pressures in Darwin suggested otherwise. Such high pressures had been a clear sign of an El Niño event in the past, so local meteorologists inferred that a major event was certainly on its way. At the very least, its impacts would be felt in parts of Australia. As Neville Nicholls reported in 1983, "[B]y about June [of 1982] the continuation of the drought [in eastern and northern Australia] throughout late winter and spring could have been expected, using long-range forecast methods first documented over fifty years ago and recently verified on independent data" (Nicholls, 1983, p. 154). Although Nicholls and his Australian colleagues were proven correct, without a computer model or a fully developed theory of the ENSO phenomenon, atmospheric scientists (including Pittock) remained sceptical about its value for climate prediction (eg. Pittock, 1984; Nicholls, 2005).

Southern change

Australian ENSO research converged with the climate change agenda at the Greenhouse 87 conference in Melbourne. This conference represented the culmination of Australian research efforts following two significant developments in the mid-1980s. In 1985, at the joint United Nations Environment Program, World Meteorological Organization and International Council of Scientific Unions (ICSU) meeting in the Austrian town of Villach, participating scientists agreed that increasing concentrations of greenhouse gases would lead to an unprecedented rise in global mean temperature in the first half of the twenty-first century. More important for this argument, they also concluded that climate data from the past could no longer provide a reliable guide to future conditions. The limits of "normal" required redefinition, and resource managers had to expect changes lay ahead. The outcomes of the Villach meeting were reinforced by the publication of a major report by the Scientific Committee on Problems of the Environment, a committee of the ICSU (Bolin *et al.*, 1986).

To inform policymakers and the general public of the implications of such scientific findings, the federal Labour government worked with CSIRO to convene the Greenhouse 87 Conference. Participants at the Greenhouse 87 conference had focused on how the Australian region could prepare for what the changed climate might be like in the year 2030. Delegates from Australia and New Zealand agreed that "research undertaken in the Northern Hemisphere to produce regional assessments will have only limited application here" in the South Pacific and more local collaborations would have to improve climate modelling in the region (Bee *et al.*, 1988, p. 609). Scientists' growing awareness of the diverse manifestations of anthropogenic climate change combined with their improving technical capacity to produce regional climate models that could inform policymaking and preparedness.

The basis of the 1987 conference discussions was a scenario of the possible effects of climate change on Australia by 2030, devised by CSIRO climate scientist Pittock (1988a, pp. 737–740). The scenario depicted a significantly drier future for the southwest of the continent, with reduced rainfall and stream flow in the region. In the late 1970s and early 1980s, Pittock and his New Zealand colleague Jim Salinger, had produced the only regional studies of the potential socioeconomic and agricultural impacts of global warming (Salinger, 1982; Pittock and Salinger, 1982). The basis for these early scenarios was the consensus predictions of the National Academy of Sciences (US), which had suggested in 1979 that a doubling of atmospheric carbon dioxide was likely to occur in the next fifty years, leading to a warming of the lower atmosphere. As Salinger noted in 1982, "If intelligent decisions are to be made … the need for these initial estimates of regional climatic fluctuations is urgent" (Salinger, 1982, p. 14).

The Greenhouse 87 participants recommended improving understanding of factors affecting rainfall, such as ENSO, to improve seasonal rainfall prediction and international cooperation on research projects, particularly within the South Pacific region and the Southern Hemisphere. Among the participants at Greenhouse 87 were hydrologists from the Water Authority of Western Australia. They postulated that Pittock's expected decline in rainfall might have already commenced in the early 1970s (Sadler *et al.*, 1988). Over a decade earlier in 1975, the potential impact of climate change on the agricultural areas of Western Australia had been canvassed at the Australasian Conference on Climate and Climatic Change in Melbourne. There, a Bureau of Meteorology researcher had speculated on the implications of a regional drying trend in the southwest, which he estimated had commenced prior to World War One (Coughlan, 1978).

The concerns expressed by Western Australian hydrologists at the Greenhouse 87 conference led to closer scrutiny of the Southwest's rainfall decline under a new research agreement between CSIRO and the Western Australian government. Following a meeting of the Australian Environment Council in July 1988, several of the state and territory governments entered into research agreements with the CSIRO Division of Atmospheric Research to study the regional implications of the enhanced greenhouse effect (Whetton *et al.*, 2016). These arrangements were prepared in the wake of the Toronto declaration earlier that year, to which some Australian state governments aligned their own targets to reduce greenhouse emissions. The research agreement formed part of the broader CSIRO Climate Change Research Program that commenced in 1989 with funding from the federal Labour government (Pittock and Allan, 1990).

The Division of Atmospheric Research had gained increasing influence in the 1980s through its contributions to international research on the enhanced greenhouse effect and on the phenomenon of nuclear winter. During the mid-1980s, the federal government had requested that the division investigate the potential climatic effects of nuclear war on Australia (Collis, 2002). The government allocated extra funds for this research, which would be used to develop and apply computer climate models for the Australian region. The primary researcher on this project was Barrie Pittock, who continued to be closely involved in modelling the potential climate impacts of the greenhouse effect. Reflecting on these threats, he observed in 1988, that they "stretch out knowledge of the atmosphere and the oceans beyond our direct experience. This presents a number of conceptual dangers as we seek to extrapolate from the present climate, and to use models based on the present climate" (Pittock, 1988b, p. 630).

Soon after, the World Meteorological Organization and the United Nations Environment Program joined forces to establish the Intergovernmental Panel on Climate Change (IPCC). During the early 1990s, the federal and state governments directed the focus of national science towards the study of regional climates in order to support the nation's international commitments to counter the enhanced greenhouse effect. For the federal labour government, keenly aware of the need to navigate and manage electorally significant environmental issues, such climate initiatives supported its claim of being the greenest of the major parties (see Morgan, 2011). Furthermore, the greenhouse issue complemented the government's other efforts in terms of ecological sustainable development and drought assistance. The significance of such research was heightened by findings that the 1980s had been the hottest decade in more than a hundred years and that the Southern Hemisphere had experienced a general warming trend during the twentieth century.

In southwestern Australia, the prospect of an ongoing dry spell focused research attentions on the impact of winter rainfall decline on agricultural productivity. The focus of CSIRO research under the agreement with the Western Australian government turned to the possible impact of this warming trend on regional rainfall. As Pittock had posited in the early 1980s, the pattern of rainfall change during the twentieth century could reveal the possible implications of global warming for regional precipitation in the future. The researchers focused their analysis of southwest rainfall records on the winter months of June, July and August, in which the region received most of its rainfall. Researchers again observed a downward trend since the 1940s, which became more marked from the mid-1960s (Pittock and Allan, 1990). Bureau of Meteorology researchers concurred with these findings and noted the significance of changes in regional rainfall for agricultural productivity (Nicholls and Lavery, 1992).

By the early 1990s, Pittock was heading up what had become the Climate Impact Group, which operated across several divisions of CSIRO. He identified the need to access climate scenario data from an Australian computer climate model with the necessary horizontal resolution over Australia, good regional input data and collaboration with relevant expert groups studying potential impacts on various sectors and interests. It was not sufficient to import a model from elsewhere – as Pittock observed, "As most GCMs (global climate models) are built by groups in the Northern Hemisphere, it is perhaps not surprising that . . . their GCMs have tended to behave poorly in the Southern Hemisphere" (Pittock, 1992, p. 18). For instance, the Climate Impact Group found that only the locally developed CSIRO4 model could replicate Australia's present climate conditions, in contrast to the models devised by the UK Meteorological Office, the Geophysical Fluid Dynamics Laboratory at Princeton and the Goddard Institute of Space Studies (Pittock, 1990; Whetton *et al.*, 1994). Until a local model was developed in the early 1990s, CSIRO projections mainly used expert judgement and historical data to produce regional scenarios of climate change (Whetton *et al.*, 2016).

For the federal Labour government, this scientific research complemented its political strategy to engage with the emerging international framework of climate governance. Following the first meeting of the IPCC in late 1988, the government observed the "need for a special contribution to research by Australia, in view of the possible major differences in climate change scenarios between hemispheres, and its position as the major [developed] Southern Hemisphere country on the panel" (DASETT, 1988). The Prime Minister argued in 1989 that, "It's important that Australia with our capacities and resources should see that there is introduced as much as possible into the international work that's being done, a consideration of the impacts and implications of these important matters for the Southern Hemisphere" (Hawke, 1989).

Government ministers urged Australia's close involvement in these matters, not only to understand the effects of climate change on the continent, but also to avoid "having foisted upon us policies which will prejudice our international and domestic economic interests" (Richardson *et al.*, 1989). Hosting the Fourth International Conference on Southern Hemisphere Meteorology and Oceanography in early 1993 in Hobart, Tasmania, was the culmination of sustained government efforts to attract a major conference of this nature, which would highlight Australian research on Australian soil (Richardson *et al.*, 1989). The conference was a joint meeting of the Australian Meteorological and Oceanographic Society and American Meteorological Society (AMS), the latter of which had held Southern Hemisphere conferences every three years since 1983. This was the first to be held in Australia, after conferences in Brazil (1983), New Zealand (1986) and Argentina (1989) (Karoly and Rosen, 1994). By the early 1990s, Australian measurements of local signals and manifestations of climate variability and change had transformed the country's airs and water into significant fields for the global climate system and its study. Connecting to the ever-growing network of climate knowledge-making, Australian researchers and governments hoped, would provide insights that they could then "relocalise" into "locally relevant information" to guide resource management and climate policy (Miller, 2004, p. 83).

Conclusion

In 1995, on the eve of the twentieth anniversary of the baseline air pollution monitoring program at Cape Grim, Paul Crutzen wrote from Germany to celebrate the efforts of Australian scientists in the areas of atmospheric chemistry and climate research. In the foreword of the annual *Baseline* report, Crutzen noted that it was the first year that CFC gases were not manufactured in industrial nations. Having pioneered their study in the mid-1970s, the newly awarded Nobel Laureate estimated that it would take more than half a century before the ozone hole disappeared (Crutzen, 1996, p. iii). Crutzen also observed that in terms of the "long-lived gases" such as carbon dioxide and CFCs, there was no significant difference in the growth rates on either side of the equator. Although he attributed these gases to the industrial and agricultural emissions of the Northern Hemisphere, he pointed to the growing atmospheric footprint of biomass burning in the tropics and subtropics of the Southern Hemisphere. "Remoteness to emissions does not imply a weaker impact," he warned, citing the appearance of the ozone hole over Antarctica as a case in point (Crutzen, 1996, p. iii).

Crutzen's foreword underlined the scientific and geopolitical imperatives that had guided the engagement of Australian researchers with the rise of international networks of climate science and governance since at least the 1960s. As a member of the Global North situated among the less developed nations south of the equator, Australian scientists believed themselves to be uniquely equipped to contribute to understanding the workings of the Southern Hemisphere and the global climate. As this article has shown, the geographic position of the Australian continent provided them key sites at which to monitor, measure and interpret the changing composition of the atmosphere at Cape Grim. This position offered them a means to overcome the "influence poverty" (Lahsen, 2007; Najam, 2005) arising from Australia's geopolitical status and formed part of the nation's wider practice of Cold War scientific internationalism.

Engaging in these international research endeavours not only enhanced the standing of Australian science, but also contributed to understanding the ways in which the global climate affected Australian environments and livelihoods. Devising means by which to interpret the regional effects of climate variability, in terms of ENSO and climate change, in terms of climate modelling, Australian scientists made clear the complex ways in which the continent was anything but remote or distant from emerging concerns about a warming world. In terms of the former, the study of ENSO belonged to an ongoing nation-building project to improve seasonal forecasting that was more concerned with local interests, than the theoretical workings of a global phenomenon; a focus that contributed to the marginalisation of this work from the wider production of climate knowledge. Meanwhile, Australian climate scientists developed their own climate models in order to downscale global climate projections to local levels that trans-Atlantic models served poorly. This government supported research reflected a longer tradition of applied (climate) science in Australia, while the development of such models for Australian climate conditions reflected the nation's technical and financial capacities. A locally developed model, in turn, demonstrated Australia's Northern credentials in the production of global knowledge (cf. Lahsen, 2004). Alive to Australia's contribution to rising levels of carbon dioxide, the federal government found in this research a means to engage with, and negotiate, nascent frameworks of international climate governance from the late 1980s.

Examining the engagement of Australian climate scientists and policymakers with global climate science production and governance during the 1970 and 1980s sheds light on the histories of infrastructural geopolitics that continue to shape global climate politics and climate change adaptation research. The ways in which Australian actors negotiated these emerging concerns reflected not only the interests of scientific endeavour and global knowledge production, but also the concerns of a nation preoccupied with its geopolitical position and vulnerability to climate change and variability. "Observing the observers", as this article attempts, makes clear the ways in which Australian climate scientists and policymakers were alive to the colonial geopolitics of knowledge that continued to order the Cold War world. In atmospheric monitoring, ENSO research and regional climate models, they found venues by which to elevate Australia's position in the arena of global climate science, while serving the nation's interests at home.

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