From weather modification to climate change:

The work of Gordon J.F. MacDonald

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1. Introduction

In current debates over global climate change, skeptics of global warming have frequently asserted a lack of scientific consensus. These assertions are largely without foundation: both the statements of major scientific societies and the lion's share of published articles in refereed scientific journals, reveal a strong expert consensus that global climate change is occurring, and that human activities are part of the reason why. But one aspect of the debate not often noted by climate contrarians, but which they might exploit if they thought about it, is that not very long ago most earth scientists held the opposite view. They believed that Earth was cooling. Throughout most of the history of science, geologists and geophysicists believed that Earth history was characterized by progressive, steady, *cooling*.

In the 19th century, this view was supported by physical theories that placed the origins of Earth in the nebular hypothesis. In the 20th century, temperature records seemed to provide independent evidence consistent this larger framework: global temperatures seemed to reveal a small, but noticeable, cooling. In the 1950s, 60s,

and even into the early 1970s, the dominant view was that Earth was cooling, and some even worried about the "coming ice age."

The late 20th century saw a reversal of scientific opinion. In the mid to late 1970s, some earth scientists began to assert that Earth was warming. When the 1980s were the hottest decade on record, both scientists and the general public began to pay close attention. In the 1990s, global temperatures continued to rise, and, as they did, scientific opinion converged around a new consensus. This abrupt about-face—from cooling to warming—might be seen as undermining the credibility of climate science and bolstering skepticism. If scientific knowledge can be characterized as the convergence of expert opinion, then this kind of abrupt reversal of opinion might undermine our confidence in that knowledge, unless we can give a convincing account of the empirical reasons behind that reversal, and the historical context in which those reasons became persuasive. This paper examines the matter through the experience of one influential individual: Gordon J.F. MacDonald.

2. The 19th and Early-Mid 20th Centuries: Secular Cooling and the Ice Ages

Through out the nineteenth century, most geologists believed that Earth was warmer in past. For geologists living and working in Great Britain and Central Europe, this belief was in the nature of an obvious fact: fossils found throughout the geological record indicated warmer conditions in the past. These geological impressions were independently supported by the dominant geophysical views of the period: that the

Earth had formed by hot accretion. In the latter part of the century, the secular cooling framework received corroboration in the development of thermodynamics, which implied that progressive heat loss was an inevitable aspect of any physical system.

In the early twentieth century, attention began to shift. As James Fleming and Spencer Weart have documented, a few scientists, most notably Svante Arrhenius, T.C. Chamberlin, and G.S. Callendar began to consider the possible effects of increased atmospheric CO_2 on Earth climate. [1] In Chamberlin's case, this interest arose out of his extensive geological work, as chief of glacial division USGS (1881-1904), on Pleistocene glaciation. Detailed field mapping had demonstrated that "the Ice Age" was not singular, but multiple, consisting of at least two and perhaps as many as half a dozen separate glacial maxima, separated by distinct inter-glacial periods in which the climate warmed radically and continental glaciers retreated to very high latitudes. One consequence of this was the realization that humans have been living not after, but *in*, the Pleistocene. As these ideas were publicized, the trope of the "coming ice age" became widespread, garnering considerable public interest and even concern.

Whereas the time frame of geophysical speculation had been billions to millions of years, the time frame of glacial geology was millions to thousands. With the development of radiocarbon dating techniques in the mid century, the most recent

glacial maximum was temporally located only ten to twelve thousand years ago. This was well within the time frame of human evolution—indeed, it increasingly appeared that it *was* the time-frame of human cultural evolution.[2] Global climate change was a relevant, perhaps even causal factor, in the evolution, migration, and cultural adaptations of human communities. Climate change could affect *us*.

3. From secular cooling to global warming

Focus on the ice ages explains how humans came to view climate change as something that could affect them, but how and why did geologists shift their attention from cooling to warming? The answer is, at least in part, through research on weather modification. A major concern of U.S. weather modification projects was unintended consequences, which led MacDonald (and others) to consider how various constituents, added to the atmosphere, might cause what they labeled 'inadvertent weather modification.' Chief among these constitunents was carbon dioxide, which U.S. government scientific advisory committees acknowledged as early as 1965 might induce global warming.

By the early 1970s, the work of Charles Keeling had clearly shown that CO_2 levels had risen dramatically in response to fossil fuel burning..[3] While it would take some years before Keeling's work gained widespread attention, the basic argument was clear. Human activities could affect both weather and climate, and Keeling's documentation of the rapid rise in CO_2 made it likely that warming effects would

happen in time, if they had not occurred already.[4] In time, global temperatures did indeed appear to show an effect, as the 1980s became the hottest decade on record.

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[1] Fleming, Historical Perspectives; Weart, Discovery of Global Warming.

[2] Libby, Radiocarbon dating, (Chicago, 1955 (2nd edition); see also Carl O Sauer, 1957, The End of the Ice Age and its Witnesses, Geographical Review, 47 (1): 29-43, and refs cit. Therein.

[3] MacDonald, Climatic Consequences of Increased Carbon Dioxide in the Atmosphere, in Power Generation and Environmental Change, 1971, edited by David A. Berkowitz and Arthur M. Squires, Cambridge: MIT Press, on pp 246-262.

[4] MacDonald, 1982, The Long-term Impacts of Increasing Atmospheric Carbon Dioxide Levels," JASON Technical Report JSR-78-07 and JSR 789-04.