Climate dynamics, science dynamics, and technological change, 1804-2004

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This paper examines the dynamic nature of climate change from the late enlightenment through the twentieth century. While the Earth's climate has experienced some notable changes over the past two centuries, both the science of climate change and popular ideas about climate have undergone complete revolutions. So too has technology, which in two hundred years has transformed an earlier pastoral/agricultural order into our current post-industrial society, with major implications for our experience of weather and climate.

Climate Dynamics and Science Dynamics

Before 1804, near the end of the "little ice age," climate discourse was dominated by Enlightenment and colonial considerations linking climate, culture, and settlement (Fleming 1998). By 1854 the fledgling science of climatology was developing based in large part on the expansion of observations and data collection networks (Fleming 1990) and the publication of synthetic works (Blodget 1857, Vesselovski 1857, Schott 1876). Circa 1904, with global temperatures a bit cooler than today, climate discourse was informed largely by cosmic physics (Croll 1875, Arrhenius 1896, Chamberlin 1899), with concerns about anthropogenic emissions and cultural implications being voiced (Ekholm 1901, Huntington 1915). By 1954, although the CO_2 and astronomical theories had officially fallen out of favor, they were beginning to make a comeback (Callendar 1938, Brooks 1950, Panofsky 1956, Plass 1956), electronic computing was in its infancy, and the International Geophysical Year (IGY) was still being planned (Handel and Risbey 1992, Harper 2003, Weart 2003). As of 2004, the field of "climate affairs" has expanded to include the science, politics, and social dimensions of a vast array of interrelated concerns and activities (Burroughs 2001, IPCC 2001, Glantz 2003).

If scientists who are passionate about change study climate dynamics ($\Delta C/\Delta t$), then we can say that historians of science, who are also passionate about change, study science dynamics ($\Delta S/\Delta t$) and the historiography of science -- or the dynamics of science dynamics ($\Delta^2 S/\Delta t^2$). On decades-to-centuries time scales, theories, institutions, and practices related to climatic change have changed dramatically -- more dramatically than the climate itself. Our interpretations of the meanings of climate are also changing. The rate of change of climate *ideas* is quite stunning and is worthy of study. This implies that students of climate dynamics should also become students of science dynamics.

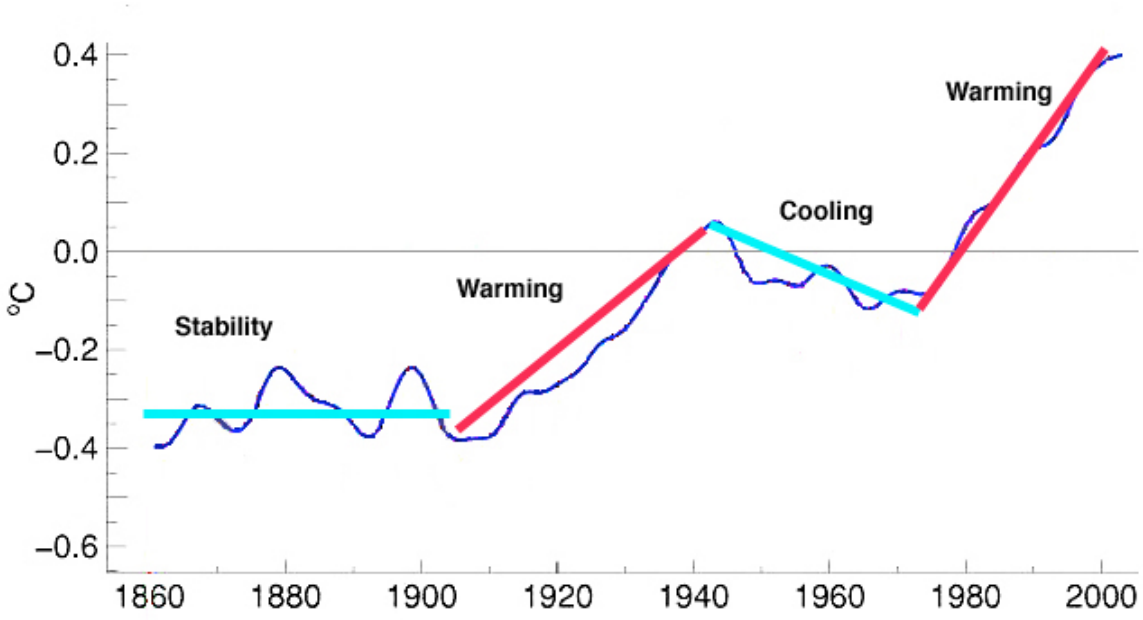

Fig. 1: Historically, climate discourse has followed the temperature trend.

Technological Change

In addition to the synthesis of climate dynamics and science dynamics, an opportunity exists for historians to examine further the history of technology in light of weather and climate affairs. To cite two examples: • In the 1930s rural electrification brought new phenomena (power *and* power outages) to farm communities; • The IGY, 1957-58, was a year of active sun, but only one space satellite, Sputnik. By way of contrast 2003, also a year of active sun, stimulated the development of the field of space weather forecasting, given the perceived vulnerability of a massive satellite communications infrastructure. Again the scale and pace of technological change ($\Delta T/\Delta t$) far exceeds that of natural environmental change.

Since the dawn of the nineteenth century, the world has experienced at least three major technological revolutions which have transformed the way humans live, work, and play, while providing the technological infrastructure for the development of modern science, and also changing the meaning and experience of the weather and climate. Following an extremely long (but not at all static) period of human experience before 1800 that may be broadly characterized as agricultural or pastoral, the rate of technological change accelerated dramatically with two major technological eras – the industrial and the post-industrial -- occurring in the past two centuries. These revolutions have fundamentally altered humanity's interaction with nature, both in the sense of the built environment, which mediates our perceptions of the weather, and in the sense of instruments that transform scientists' ability to observe, analyze, and predict it.

Lewis Mumford (1934) employed the terms Eo-technic (from Eos goddess of the dawn), Paleo-technic (for early industrial technology) and Neo-technic (for the possibilities of modern late- to post-industrial society) to capture this dynamic and to distinguish major eras

in the history of human relations with the machine. His was a dialectic that led from early pastoral equilibrium, through social breakdown associated with mass production, to the possibility of renewal in his own times. Table 1 presents a summary and expansion of Mumford's categories including the very recent (Eco-technic) hope that a new era is dawning, in large part driven by widespread concerns about climatic change and the quest for environmental and social justice.

Table 1. PERIODIZATION OF THE HISTORY OF TECHNOLOGY

Adapted from Lewis Mumford, *Technics and Civilization*(1934).

ERA	ENERGY	MATERIALS	ARTIFACTS	METAPHORS
Paleolithic Before 10,000 BCE	Muscle	Stone/Bone	Stone tools	Survival
Eo-technic 10,000 BCE to 1750 AD	Water Wind	Wood Cloth Animals Leather	Clipper Ship Water Wheel Violin	Agriculture Pastoralists Artisans
Paleo-technic 1750-1930	Steam	Coal Iron	Railroads Factories Bridges	Industry Pollution Mass Production
Neo-technic 1930-2000	Electricity Oil Nuclear	Aluminum Plastics "Disposable"	Automobiles Airplanes	High-tech Toxic chemicals Mass Consumption
Eco-technic* 21st century	Renewable Sunlight Wind Water	Reusable Biodegradable Recyclable	Low Impact More Natural Fuel Cell Compost Pile	Less is more Global equity Local focus Survival

* The term "Eco-technic," going one step beyond Mumford, recognizes that humanity will always produce technologies, yet must always live within the limits of an ecosystem.

Mumford's hope for a return to humane living in the Neo-technic era was frustrated by the dawning of a "disposable" society of mass consumption that generated weapons of mass destruction and greenhouse gases and toxic pollutants in amounts never before experienced. Whether the course of climate affairs stimulates a utopian new Eco-technic era or, more likely, a number of heterotopian responses or even dystopian excursions into climate engineering, remains to be seen (Keith 2000, Fleming 2004). What is not controversial is that a complete understanding of climate dynamics will be informed by the study of science dynamics and technological change.

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