PROLOGUE:
SMOG, HAZE, SULPHUR: THE ELUSIVE CLARITY OF THE ANTHROPOCENE[*]

1. The Great London Smog (1952)

Photo A: The Great London Smog:

Street scene with double decker buses on a smoggy November afternoon in London. This photo was taken in 1953, the year after the deadly smog episode between 5 and 10 December 1952. Photo: AKG-Images

The air became stagnant as a high pressure system settled in over the Thames River valley on the morning of Friday 5 December 1952. It had been a cold night—another in what had turned out to be an unusually frigid autumn—and in each home a pile of bituminous heating coal smoldered over an open grate. By morning, the city's low-level chimneys had filled the air with smoke. But the air above the city's stagnant hazy curtain warmed more quickly than the air below, resulting in a temperature inversion. Emissions from Europe's largest city were now effectively trapped within a thin band of cold air approximately 100-200 meters deep.

The yellow-gray smog deepened as London's emissions were stoked by the daylight pattern of work and commerce. In the morning people were shuttled to their jobs on the city's new fleet of double decker diesel buses.[1] Emissions from factories on London's East End kicked in,

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[1] The program to replace the aging electric tram system with the iconic red buses had been just been completed five months earlier.

lending yet another source of coal smoke to the thickening smog. A wide array of public and private activities now worked in concert—from the tail pipes of buses, to the smoke stacks of power-generating stations, and the thousands of stoves preparing Friday evening's dinner—the combined action of a society in motion dropped visibility below ten meters. By evening, navigating the city became impossible (see Photo A). According to Laskin (2006: 44), "Residents described slow-motion car crashes, pedestrians groping their way along walls and fences, people drowning after stumbling into the River Thames, and long lines of motorists blindly following the taillights of the cars ahead and ending up hopelessly lost in an unusually cool autumn."

Beyond the physical features of their city, the smog obscured the accumulation of deadly levels of fine particulate matter and sulphur dioxide gas. For four days the pollutants were sustained at levels never attained again in any city since. The effect on the lungs of London's war-weakened population was swift, although this was not immediately clear to Londoners. As a physician at a central London hospital recalled, "There was no sense of drama or emergency. It was only when the registrar general published the mortality figures three weeks later that everybody realized that there had, in fact, been a major disaster" (Nagourney, 2003). It is estimated that the Great London Smog claimed the lives of 12,000 people, prompting Hunt and his colleagues (2003: 1209) to declare that "the smog event of 1952 was, in terms of human health effects, the most calamitous of the century."

But preventing the smog by regulating London's pollution was a daunting task: the pollution was not only bound up with how Londoners worked, moved about the city, and generated economic activity, but with their private lives as well. Widely-used household heating technology would need to be changed, likely at considerable private expense (Brimblecombe, 2006; Sanderson, 1961). Regulation was additionally problematic given the historic role of the national government in upholding the rights of private householders against the regulatory authority of municipal governments in matters of public health; central regulation would mean remaking long-standing political structures (Keeble, 1978).[2] So it was not altogether surprising when the newly elected Conservative government led by Winston Churchill was reluctant to advance a legislative solution. In fact, the government downplayed the severity of the event (Scarrow, 1972) and seven months passed before they were eventually forced to hold a public enquiry (Keeble, 1978).

Yet, the incident appeared to signal a growing change within society itself. While there had always been discontent with the poor environmental quality of industrial production, it was previously relegated to "a tolerable nuisance" as it appeared interconnected with the capacity of society to generate employment (McNeill, 2000: 59).[3] But a broad and growing discontent with air pollution – one that could not simply be explained as the straightforward reaction to the physical concentration of particulate matter in the atmosphere – began to surface across most industrialized counties after WWII. It was these discontents that became the grounds for the political compact that came to dominate much of the twentieth century, in which the social need for regulating pollution was translated into national environmental legislation enforced and monitored by state agencies. Significantly, the devastation of the Great London Smog positioned

[2] The 1936 Public Health Act, for example, placed restrictions on municipal governments from being able to prosecute homeowners for issues associated with domestic chimneys (Keeble, 1978: 262).

[3] As McNeill (2000: 93) recounts, the nineteenth century civic anthem of Japan's first large steel town, the advancement of coal-based industry was viewed as a source of civic pride: "Billows of smoke filling the sky. Our steel plant, a grandeur unmatched: Yawata, O Yawata, our city!"

the U.K. at the forefront of this trend, and in 1956 the House of Commons enacted the Clean Air Act - making the United Kingdom the first country in the world to pass a national statute for regulating air pollution.[4]

Although air quality in the U.K. eventually improved, this was largely the product of deep changes taking place in society itself—changes not intended by the regulation enacted under the Clean Air Act. The three decades following WWII (from 1945 to approximately 1973) marked a tremendous transformation, not only in the U.K. but across all industrialized countries. The transformation may not have been readily apparent to Londoners the year of the smog as it marked another portentous event: the end of four years of reconstruction aid from the U.S. via the Marshall Plan. In spite of the aid, the U.K. remained highly indebted, and moreover faced considerable turbulence with the double indemnity in 1956 of both a major military defeat in Egypt (the Suez Crisis) and an economic recession (i.e., the same year the Clean Air Act was enacted) (Heyck, 2008). Yet, by the end of the 1950s, the investment in industrial infrastructure was paying dividends, resulting in the most rapid economic expansion seen in the country since the 1870s, topping 4% GDP in 1959 (Heyck, 2008). Moreover, the historically low levels of unemployment that began after the war (i.e., below 2%) were sustained for 30 years, something that had not occurred before or since in the U.K. The persistence of low unemployment was matched by an 80% increase in real earnings across this period, and these factors combined with the increased security created by the newly formed national welfare system, to bring about a sharp rise in domestic consumer spending. By the early 1970s, over half of households owned their own home and these dwellings were well-stocked with newly manufactured appliances such as dishwashers, television sets and refrigerators (Donnelly, 2014; Heyck, 2008). Over half of the households also owned an automobile.[5]

These social transformations far outpaced the scope of the Clean Air Act and established a pattern whereby attempts to regulate pollution invariably lagged behind changes in society (Brimblecombe, 2006). Coal grates and cooking stoves largely disappeared, not because of new statutes for "smokeless" areas, but because almost a million units of old housing stock were replaced between 1955-1970 and switched to inexpensive and more convenient all-electric or gas-fired appliances (Scarrow, 1972). Industrial coal smoke also left the inner city as heavy industry was largely phased out and replaced with new and more efficient industries centered on the manufacture of automotives, electronics, and aerospace in factories located in new suburban

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[4] Significantly, the 1956 Clean Air Act predated even the landmark U.S. 1970 Clean Air Act by more than a decade. A decisive factor in the passing of the Act in the U.K. was the emergence the National Smoke Abatement Society, a relatively obscure lobbying group at the time. The Society grew to prominence after the smog and its concerted lobbying effort played a pivotal in advancing the legislation (Scarrow, 1972). Extra-parliamentary environmental interest groups subsequently became a key element in the formation of national environmental policy in other industrial countries. Paradoxically, in spite of the success of the Society in advancing the 1956 Clean Air Act, the role of environmental groups in the U.K. remained quite small until the 1990s (McGrew, 1990) and was dwarfed by the broad movements that emerged in the 1970s in both the U.S. (Gottlieb, 2005 [1994]) and West Germany (Mewes, 1983).

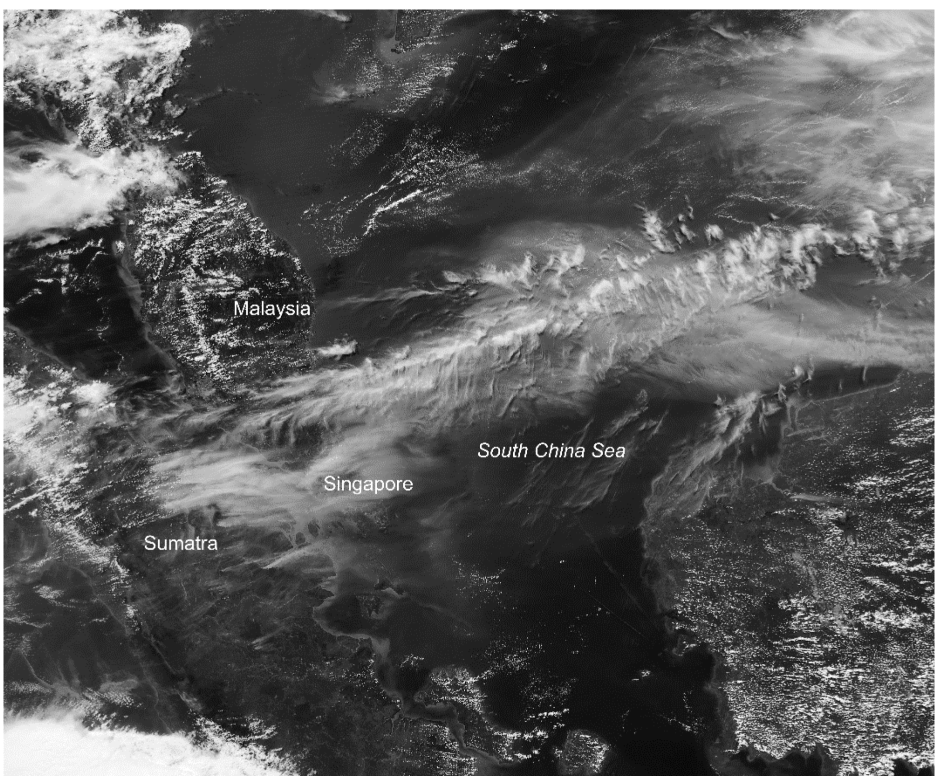
[5] But, as we discuss in Chapter 3, the transformations expanded far beyond economic dimensions, across to most every facet of life. The distinct class differences in British society in the nineteenth century seemed to erode as patterns of fashion and culture changed into the "classless" world of blue jeans and the pop music (Donnelly, 2014). In their place social discontents increasingly centered on new divisions – race and gender – as low unemployment resulted in the massive influx of immigrants from the West Indies, Africa, India and Pakistan, and enabled women to enter the workforce in large numbers (Heyck, 2008). Moreover, sustained affluence paradoxically generated a counter-culture that questioned the desirability of the current and prosperous form of society, which significantly included the environmental movement (McGrew, 1990).

developments. Moreover, coal use itself began to decline. A month after the passage of the Clean Air Act, the world's first nuclear power generating plant was connected to the British electrical grid. Flash forward to a decade later and domestic coal consumption had declined by almost 40% and was set to decline even more precipitously with the discovery of natural gas in the North Sea in 1967. It has now been almost 40 years since Britain built its last coal-fired plant.

Yet, the history of pollution from 1952 to the present is not one of straightforward social progress. It might be more accurate to say that the problem of atmospheric pollution has not so much been improved but *transformed*. Although coal smoke and sulphur dioxide have grown to be relatively minor problems in the U.K., as it has across all the industrial centers that emerged in the decades following WWII (e.g., in London, Tokyo, Rhine-Ruhr Germany, the U.S. Rust Belt), pollution from coal burning has shifted to new centers such as Shanghai (China), Ho Chi Minh City (Vietnam) and Sao Paulo (Brazil) (Fenger, 1999). However, the decline of public transit relative to the rise in automobile traffic has generated new pollutants in cities like London, including volatile organic compounds, nitrogen oxides and ozone (Brimblecombe, 2006). More significantly, pollution has ceased to be something that only causes harm in the region adjacent to the emission source, as the scale at which the effects of pollution are felt has telescoped. Today, the most mundane features of social life (such as driving a car to work) effectively contribute to the alteration of the planetary systems that regulate climate. The form of society that ultimately raised the Great Smog of London in 1952 continues to exceed efforts to meaningfully regulate it.

Southeastern Asian Haze (2013)

Photo B: Southeastern Asian Haze



A satellite image taken on June 19, 2013 of smoke from wildfires from oil palm-growing regions on the Indonesian island of Sumatra blowing east toward southern Malaysia and Singapore. The smoke formed a thick haze in Singapore and by the evening broke all previous record for smog severity. But even these levels were exceeded in subsequent days. Photo: NASA Earth Observatory

Unlike the Great London Smog, the Southeastern Asian Haze of 2013 did not originate in the two hardest hit cities: Singapore and Kuala Lumpur. Instead, it was carried by winds across the narrow Strait of Malacca from massive fires[6] hundreds of kilometers to the west in the Riau province in eastern Sumatra, Indonesia, as shown in Photo B. Levels of particulate pollution in Singapore (the worst hit of the two cities) doubled previous records, as the Pollutant Standard Index reached levels deemed “very unhealthy” for three consecutive days (Gaveau et al., 2014). Although the fires burned for a little less than two weeks (the bulk of the burning was confined to a five day span), they constituted 5-10% of all Indonesian greenhouse gas (GHG) emissions in 2013 (Gaveau et al., 2014). These unusually high emissions, however, did not result from the burning of the forest, but from the underlying tropical peat—the largest near-surface reserve of terrestrial carbon on the planet. Indeed, there is more carbon sequestered in the region’s tropical peat than all the proven reserves of oil on the planet.[7]

The Great London Smog and the Southeast Asian Haze bracket the era of environmental politics in a remarkable way. If the Great London Smog expressed the need for society to better regulate environmental quality, the Southeast Asian Haze represents a dimension of how society subsequently took up that task. Although the fires were plainly associated with clearing land for the expansion of oil palm plantations (Gaveau et al., 2014), this expansion was, ironically, intended not to increase, but rather to decrease GHG emissions.[8]

Besides being used as a feedstock in the manufacture of a vast array of products (from lipstick to chocolate), oil palm has become a key part of the E.U.’s renewable energy strategy through its role in biodiesel production (Field et al., 2008; Koh and Ghazoul, 2008). In principle, blending biofuels with fossil fuels slows GHG emissions because biofuel feedstock (e.g., oil palm, but also soybean and temperate zone oilseed rape) fixes atmospheric carbon dioxide as it grows. In the early 2000s this principle was met with enthusiastic support from policy-makers,

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[6] The fires covered 163,000 hectares, just over half of the area of Yosemite National Park in California.

[7] But this was by no means the first such fire. A much larger Indonesian fire in 1997 released anywhere from 13-40% the global annual carbon generated from the combustion of fossil fuels *globally* that year (Page et al., 2002). In fact, the 1997 fire resulted in the largest annual increase in atmospheric carbon dioxide ever recorded.

[8] There is little doubt that the fires are connected to the expansion of oil palm. Careful analysis of 2013 LANDSAT satellite imagery highlights a peculiar socio-ecological dynamic set off by the increased demand for biodiesel. The expansion of oil palm has largely come at the expense of the regions’ forest cover (Koh and Ghazoul, 2008; Lian Pin and Wilcove, 2007). Reduced forest cover means even relatively short dry periods (less than 2 months) increase fire hazard significantly (e.g., by increasing soil temperature and changing hydrological patterns). Consequently, blazes can occur even in a wetter-than-average year like 2013 (Gaveau et al., 2014). This changed fire ecology combined with a dispersed pattern of ignition coinciding with the spatial arrangement of oil palm producers and state land use zoning. Conspicuously, over 80% of the burned land was recently cleared of forest and had either been allocated by the state to oil palm companies or had contested ownership. Fire—the quickest and most cost-effective manner of clearing coarse woody debris from such fields—was being targeted to land most suitable for expanding oil palm. Within a month aerial drones spotted excavators preparing the recently burned site for planting. Biophysical dimensions of the forest, including fire ecology, hydrological cycles, not to mention planetary carbon regulation, were interacting with multiple dimensions of society. These social dimensions include not only the oil palm producers, who are driven by the stable income stream associated with oil palm and the growing awareness of global environmental threats that initially motivated biofuel policy but other seemingly unrelated socio-historical pressures as well.

particularly in the U.S. and the E.U., who were concerned with unrelated but persistent problems—namely, low farm income and the internal political pressure exerted by national farm lobby groups (Potter, 2009).

The threat of low agricultural commodity prices has plagued the farm sector through most of the twentieth century because agricultural output has tended to far surpass the amount of food that could be purchased (Friedmann, 1982, 1993). The chronic tendency of agriculture towards oversupply persisted even into the period of accelerating consumer affluence (1945-1973) and has only episodically experienced periods of high profits (e.g., 1973-1980 and 2006-2011). The first of these crises of farm income began with the collapse of the grain market in 1921 and extended well into the 1930s (Friedmann, 1982, 1993). The collapse of agricultural prices constituted a broad social crisis, since the majority of people in industrialized countries before WWII lived in rural areas. In response, national governments in the 1930s began managing agricultural prices through various forms of subsidization (e.g., import tariffs, supply management programs, payments for removing land from production, and direct payments) (Friedmann, 1982, 1993). But farm income support programs were themselves drawn into a deep crisis in the mid-1970s along with many other features of the post-WWII political and economic order.[9] Although the crisis resulted in a dramatic spike in the prices of all agricultural commodities, these increases quickly evaporated into two decades of chronic low profits.[10] As governments in these countries attempted to restructure their economies by reducing government expenditures and promoting global trade liberalization, farm income programs became increasingly difficult to justify to a primarily urbanized tax base already facing deep cuts to their own state welfare benefits (Potter, 1998; 2009).

Significantly, the critique of intensive farm management practices was one of the foundations of the modern environmental movement.[11] At the peak of the farm crisis in the 1990s, environmental groups called for state subsidies to be conditional on farmers using less intensive farm practices (Cain and Lovejoy, 2004; McGranahan et al., 2013; Potter, 1998, 2009). And state-subsidized biofuel initiatives provided an attractive mechanism to connect the concerns of urban environmentalists with rural farm communities. By producing biofuels from crops such as corn (biogasoline) or oilseed rape and soybean (biodiesel), stocks of these crops could be drawn down (increasing prices), while their displacement of fossil fuels could simultaneously reduce overall GHG emissions. Consequently, both the U.S. (2002) and E.U. member states (2003) aggressively legislated biofuel blending standards (Gerasimchuk and Koh,

[9] The long period of social stability in industrial countries following the Second World War came to an abrupt end at the beginning of the 1970s. This crisis had multiple dimensions and was felt internationally, but a key feature took the form of a severe economic crisis in the U.S., the key economic engine of the post-WWII reconstruction. A mixture of high inflation and persistent unemployment (stagflation) took hold at the end of the 1960s prompting the Nixon government to implement wage and price controls in 1971. These economic problems were immediately compounded by a steep rise in oil prices following an energy embargo by the Organization of Petroleum Exporting Countries (OPEC) in 1973. The economic slowdown strongly conditioned the restructuring of farm income support programs, particularly in the 1985 U.S. Farm Bill (McGranahan et al., 2013; Potter, 1998).

[10] The sag in the farm sector was initiated by a crash in farm commodity prices in the 1980s followed by crippling double-digit interest rates (Potter, 1998). By the end of the 1980s, over 70% of large farms in the U.S. were at risk of liquidation and expenditure on commodity support programs soared to $26 billion. Similarly, in the E.U., 70% of the entire commission budget was devoted to some form of farm income support (Friedmann, 1982, 1993).

[11] Racheal Carson's book *Silent Spring* (1962) is frequently credited with the birth of the modern environmental movement. The book focused on the negative side effects of using pesticides such as DDT to manage insect pests in intensive agricultural systems.

2013; Tyner, 2008).[12]

Blending standards initially increased demand for E.U. oilseed crops, but the excess supply of these crops was almost completely absorbed by 2006, necessitating the import of oil palm to make up the shortfall.[13] On the eve of the Southeastern Asian Haze, oil palm constituted 20% of the feedstock for E.U. biodiesel (Gerasimchuk and Koh, 2013). While the decades long problem of farm income was solved by a biofuel strategy, with food prices surging between 2006-2011 (Headey and Fan, 2008), it also led to the aggressive expansion of oil palm, which, paradoxically, hastened carbon emissions through the destruction of peat forests (Koh and Ghazoul, 2010). In light of the evidence that biofuels made from crop plants (first generation biofuels) do not reduce GHG reduction emissions, environmental groups have increasingly applied pressure on legislators to mandate second generation biofuels (made from non-crop plant sources) which would significantly reduce the farm price support dimensions of the initial strategy.[14] Sensing an opportunity, as well as a crumbling coalition, farm groups have responded by arguing that recent high prices prove the need for national self-sufficiency in food production and have called for a return to direct support of E.U. farmers (Potter, 2009). In fact, while E.U. environmentalist and farm groups find themselves increasingly on opposing sides of biofuel policy, they find common cause in the protectionist demand to limit the importation of oil palm from Indonesia and Malaysia. Yet, while such a policy may satisfy the interests of E.U. oilseed producers, it does so at the expense of the oil palm sector, which employs millions of people in Malaysia and Indonesia (Mukherjee, 2014, 2004).

The 2013 Southeast Asia Haze highlights how seemingly objective laws of modern society (e.g., the chronic tendency of agriculture towards oversupply) invariably limit our capacity to regulate damaging forms of pollution. Although these “laws” emerge from society itself, they appear rigid and unchangeable. Yet, while some astute and powerfully positioned actors can certainly advance their interests over others (e.g., E.U. farmers over Southeast Asian oil palm companies), all remain subject to a social context that no one controls. Moreover, our ability to provide lasting solutions to historic problems, such as farm income, not only seem increasingly beyond our reach but tend to compound with other unresolved problems, conditioning our ability to engage emerging environmental threats (e.g., rising GHG levels in the atmosphere).

Sulphur and the Stratosphere (1815 and the future)

> I had a dream, which was not all a dream.
> The bright sun was extinguish’d, and the stars
> Did wander darkling in the eternal space,
> Rayless, and pathless, and the icy earth
> Swung blind and blackening in the moonless air;

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[12] As a result, all E.U. diesel now contains at least 5.75% biodiesel and is set to rise to 10% in 2020.

[13] The amount of crops required to meet the blending standards proved immense. The carbon currently emitted through the combustion of fossil fuels roughly equals the amount of carbon fixed by all agricultural crops on the planet (Field et al., 2008). Moreover, the demand for liquid transport fuels is accelerating, such that by 2050 an anticipated of 2.26 billion new cars would require an estimated 54 million hectares dedicated to growing biofuel crops (Ghazoul et al., 2010).

[14] There are attempts in the E.U. underway to renegotiate the renewable fuel directive to better address the issue of GHG emissions by adding so-called Indirect Land Use Change (ILUC) provisions that mandate the amount of second generation non-crop sources of biofuel do not change agricultural land use patterns (e.g., from algae, waste and organic cellulosic residues). Predictably, these new provisions are being vigorously opposed by farm groups.

Morn came and went – and came, and brought no day,
And men forgot their passions in the dread
Of this their desolation; and all hearts
Were chill'd into a selfish prayer for light
- Excerpt from *Darkness*, Lord Byron, 1816

The largest volcanic eruption in recorded history began on the evening of Wednesday 5 April 1815 on Mount Tambora on the small Indonesian island of Sumbawa, 300km east of Bali (Oppenheimer, 2003). The first eruption was massive in its own right and was mistaken for canon fires some 350km northeast in Sulawesi. The second eruption, however, has no parallel in recorded history (Photo C).[15] The explosions began early in the evening on Monday 10th April and over the next four days 50 cubic kilometers of material flowed out as ash and magma, equivalent to 2,000 times the volume of concrete in China's massive Three Gorges hydroelectric dam. An immense amount of ash buried crops over an area four times the size of the U.K. and darkened the sky for two days. A tsunami of 1-4m was cast out and stretched across a range of at least 1,200km. Lava flows extended 20km out from the mountain, filling the island with toxic gasses that poisoned many residents. The local impact of the eruption was, without a doubt, the most devastating in history with an estimated 71,000 dead (Oppenheimer, 2003).

Photo C: Volcanos and the Stratosphere

[15] The Tambora eruption is regarded as more massive in scale than even the Aegean Minoan eruption 3,600 years earlier, and only exceeded eruption from the Campi Flegrei caldera in Italy 40,000 years ago (Oppenheimer, 2003: 253).

Alaska's Pavlof volcano eruption on 18 May 2013. Small eruptions like these are common along the Aleutian Islands, involve the displacement of less than 0.100 cubic kilometers of dense rock and generate columns of smoke less than 15 kilometers in height. Much less common are the supereruptions like that of Mount Tambora on 10 April 1815, which involve the displacement of over 300 cubic kilometers of rock and an ash clouds extending 40 kilometers (i.e., well into the stratosphere). The cooling effect of stratospheric ash from Tambora resulted in dramatic cooling in Northern Europe and the Northeastern U.S. the following summer. Climate scientists are presently looking to mimic this cooling effect as way to mitigate climate change by developing Solar-Radiation Management (SRM) technology. Photo: The Alaska Volcano Observatory / Rob Gutro, NASA Goddard Space Flight Center.

The devastation of the eruption, however, was by no means restricted to the Indonesian archipelago. The plume of ash and gas rocketed over 40km into the sky, well above the troposphere (the band containing the earth's weather and clouds) and into the stratosphere. It is estimated that a 60 Teragrams of sulphur (ten times that of the Mount Pinatubo (Philippines) eruption in June 1991) reached the stratosphere where the small particles were carried by winds longitudinally across the planet, eventually concentrating at latitudes equivalent to Northern Europe and the northern states of the U.S. The particles lingered for up to three years before falling back to earth as acidified precipitation (Stothers, 1984).

The particle clouds were first observed over England some three months after the eruption and reached peak intensity by early autumn. They appeared as richly colored sunsets and twilight during the last week of June 1815.[16] As the dust continued to mix, it gave the illusion that stars in the night sky trembled. The darkening stratosphere meant sunspots became visible.

The spectacular atmospheric display of 1815, however, was a harbinger of an oncoming disaster. The particles absorbed and reflected back solar radiation, leading to three years of historically unprecedented cold weather. In fact, 1816 became known as the "year without summer" as temperatures in Europe fell to the lowest they had been since the deepest years of the Little Ice Age in the early seventeenth century. The cool wet summers extended across Europe's grain growing regions, resulting in a trebling of prices and shortages of bread. Famine extended across northeastern France, southwestern Germany, Italy, Ireland, eastern Switzerland and across the Hapsburg Empire, surpassing even the worst famines of the eighteenth century (Post, 1977). The cold extended to North America where repeated and extensive crop failures in the New England region of the U.S. prompted widespread migration to Ohio.

Coming in the wake of twenty-five years of continuous war and the decisive defeat of Napoleon in July 1815,[17] Byron's 1816 poem *Darkness* reflects the sense of doom that shrouded Europe as the cold set in. The inner crisis of society following the French Revolution appeared to find expression in the sky; the dramatic shift of sky and climate sounded the tocsin of social decline. The sense of progress that marked the eighteenth century Enlightenment was enveloped in Romantic recoil. In the wake of the French Revolution and the 1815 restoration of the old order at the Congress of Vienna, an anti-liberal political reaction appeared to be taking grip of the continent. But change could not be so easily contained.

As the sulphur fell back to the earth (1819), Benjamin Constant would address the Athénée Royal in Paris and declare that in spite of the restoration of the monarchy in France, society could not be rolled back into its old form.[18] A new form of society, one without historical precedent, was being articulated. Both the 1952 London Smog and 2013 Southeast Asian Haze attest to the legacy of the relentless and unimaginable social and biophysical transformations that continue to advance. What Byron's despair failed to recognize, however, was the accomplishment of *bourgeois society*, in which the productivity of humanity had fully moved from the rural forms of peasant production to production in cities—and the rise of the Third Estate—the class of "commoners" who were to be judged not on the basis of tradition or divine orders but on their capacity to "work." Taking the course of humanity out of the hands of "fate," in a sense denaturalizing it, and drawing it into the sphere of responsible human activity was bound up with the "freedom thinking" of figures such as Jean Jacques Rousseau, Immanuel Kant, Adam Smith and Georg Friedrich Hegel and the attempt to advance actual freedom arising in the politics of what become known as the Left.

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[16] The sky had a characteristic look: orange-red horizon crested with deep purples and pinks that occasionally streaked with dark bands. These were exemplified in the work of that period from the British Romantic painter J.M.W. Turner in pieces such as "Sunset" (c. 1833) (Zerefos et al., 2007).

[17] The Tambora eruption occurred just as the Great Powers of Europe (the Austrian (Habsburg) Empire, France, Prussia, Russia and the British Empire) began mobilizing their armies for the decisive defeat of Napoleon in July 1815.

[18] As Constant will argue this new form of society is characterized by a fundamentally new form of political liberty that emerges from free individuals engaged in commerce: "Commerce makes the action of arbitrary power over our existence more oppressive than in the past, because, as our speculations are more varied, arbitrary power must multiply itself to reach them. But commerce also makes the action of arbitrary power easier to elude, because it changes the nature of property, which becomes, in virtue of this change, almost impossible to seize… circulation creates an invisible and invincible obstacle to the actions of social power" (Constant, 1988[1819]: 324-325).

Yet, the pattern of progress throughout the nineteenth and twentieth centuries has not been one of society freely determining itself. Both the 1952 Great London Smog and 2013 Southeast Asian Haze point towards deep social structures that have a motion of their own and to which we are all ultimately subject. The question of how society might place itself at the service of freedom has progressively grown dim. Today, society threatens to transform planetary systems in a manner that surpasses the reach of geological processes of much larger time scales. Taking up the task of improving environmental quality means taking hold of broad social processes that are seemingly more complex and incomprehensible than the dynamic chemical processes and patterns of aerosol movements in the stratosphere. Consequently, tackling a problem such as climate change (e.g., by charting a path to renewable fuels) seems to only get mired in long-standing social-structural problems (e.g., agricultural overproduction).

At the same time, the obstacles associated with reducing GHG emissions have given rise to an array of increasingly sophisticated technical solutions to climate change. One of the most controversial has been Solar-Radiation Management (SRM) technologies designed to master the process of planetary cooling that follow volcanic eruptions such as Tambora. The prominent Nobel Prize-winning atmospheric chemist Paul Crutzen explained the growing need for SRM technology in a recent editorial for the journal *Climate Change* (2006: 211-212):

> By far the preferred way… is to lower the emissions of the greenhouse gases. However, so far, attempts in that direction have been grossly unsuccessful. While stabilization of CO_2 would require a 60–80% reduction in current anthropogenic CO_2 emissions, worldwide they actually increased by 2% from 2001 to 2002, a trend, which probably will not change at least for the remaining 6-year term of the Kyoto protocol, further increasing the required emission restrictions. Therefore, although by far not the best solution, the usefulness of artificially enhancing earth's albedo and thereby cooling climate by adding sunlight reflecting aerosol in the stratosphere might again be explored and debated as a way to defuse the Catch-22 situation… [and] counteract the climate forcing of growing CO_2 emissions.

Significantly, Crutzen's response indicates the extent to which SRM technology emerges from the persisting failure to regulate pollution at the level of society. Although the very possibility of something like SRM technology would have struck figures in the Enlightenment as a great accomplishment, today it has become an index of the inability of society to freely regulate itself. Climate and atmospheric scientists have grown frustrated by efforts to reduce climate change "from below" (i.e., at the level of civil society) and have resigned themselves to technical solutions to resolve the impasse "from above." But even here the scientists find themselves increasingly blocked by the political inertia around approving small scale trials to better understand and model the dynamics and risks of stratospheric sulphur deposition (Keith, 2014, 1985; Keith, 2010, 1979). Yet inaction on SRM research, in the face of accelerating climate change, may result in even deeper dilemmas: "it would be reckless to conduct the first large-scale SRM in an emergency" (Keith et al., 2010: 426).

Crutzen and his colleagues have proposed the Anthropocene to demarcate the new geological epoch that came into being around the time of the Tambora eruption in 1815. [19] Looking back over the past two centuries we can discern something of this period by following a single element—sulphur—across history. Sulphur attains a new planetary significance through

[19] The Tambora eruption can readily be discerned in ice cores and has been proposed as a marker for the onset of the Anthropocene (Smith, 2014).

the growing crisis of human society. In 1952, there was a sense that that sulphur dioxide was an object to be shaped by government regulation. Yet this regulation was almost immediately outpaced by the explosive changes that took place in society after WWII. While the form of pollution changed, new unanticipated ecological problems emerged. But these new problems appear even more deeply connected to long-standing problems within society (and hence seem more intractable).

We now face ballooning ecological degradation that pales in comparison not only to past environmental problems (e.g., 1952), but even the kind of biophysical transformations posed by episodic geological processes (e.g., 1815). Today, sulphur presents itself to us not as a constituent part of the planet to be regulated by society—as an object through which the potential of humanity could be realized—but as an inevitability, as something that we will collectively be forced to shoot into the stratosphere because of our inability to take hold of the runaway character of society itself.