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The waning of the little ice age

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The Waning of the Little Ice Age

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**UCD SCHOOL OF ECONOMICS
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THE WANING OF THE LITTLE ICE AGE¹

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ABSTRACT

The ramifications of the Little Ice Age, a period of cooling temperatures straddling several centuries in northwestern Europe, reach far beyond meteorology into economic, political, and cultural history. The LIA has spawned a series of resonant images that range from frost fairs to contracting glaciers, and from disappearing vineyards to disappearing Viking colonies. This paper takes issue with these images, and argues that the phenomena they describe can be explained without resort to climate change.

Keywords: climate, global warming, Little Ice Age

JEL classification: N50, Q54

The Waning of the Little Ice Age

Originally applied to an era spanning several millennia in California's Sierra Nevada, the term 'Little Ice Age' (henceforth LIA) nowadays usually refers instead to a global climatic shift towards colder weather occurring during the second millennium.² Although it amounts to academic heresy to deny the existence of a LIA, considerable imprecision about its chronology, geography, and impact remains. Estimates of the timing of its onset range from the ending of a warm phase—the so-called Medieval Warm Period—that 'had already passed its peak in Greenland in the twelfth century [but] broadly continued in Europe until 1300 or 1310', to an 'abrupt beginning' in the late sixteenth century (Matthes 1939; Lamb 1995: 181; Viazzo 1989: 133). And while Emmanuel Le Roy Ladurie (2006) has referred to the cold 1850s as 'the final sigh of the Little Ice Age', others have found little evidence of an end to it before the twentieth century. Even meteorologist Hubert Lamb, one of the main popularizers of the LIA, conceded the imprecision of dating (Lamb 1995: 318). The chronology of the preceding Medieval Warm Period, identified by Lamb in 1965, is equally elastic (Lamb 1965; Bradley, Hughes, and Diaz 2003).

² For an early use of the term in a European context see Gordon Manley's comment on Ahlmann (1948: 193).

Consensus has also been lacking on the LIA's geographical reach. The Intergovernmental Panel on Climate Change's *Third Assessment Report* emphasizes the variations in climate change across regions and the possible independence of such variations, so much so that it deems the term 'LIA' a misleading guide to *global* temperature changes in the past. True, in the Northern Hemisphere the 1500-1900 period stands out, but agreement as to how much temperatures dropped there is lacking.³ The modest declines proposed by some scholars (e.g. Oerlemans 2005; Zemp *et al.* 2010) sit uncomfortably with the rhetoric of a Brian Fagan ('a climatic seesaw that swung...in volatile and sometimes disastrous shifts..., growing season was about five weeks shorter...') or a Richard Steckel ('pack ice surrounded Iceland..., havoc in northern Europe..., glaciers advanced significantly...'; 'cool temperatures and temperature variability were bad for health...') (Fagan 2000; Steckel 2005, 2010). More recent assessments of the Medieval Warm Period also reckon it to have been only moderately milder than the cooling period that followed (IPCC 2001: 2.3.3).

In a companion paper (Kelly and Ó Gráda 2011) we have set out the statistical case against the concept of a LIA. There we conclude, on

³ Estimates range from the modest 0.1-0.2°C implied by several meteorological reconstructions, through the 1.7°C employed by Steckel in a recent anthropometric analysis, to the 'about 7°C cooler than during the Medieval Warm Period' claimed by Fagan (Oerlemans 2000; Fagan 2000; Steckel 2010).

the basis of an extensive analysis of a range of constructed and instrumental series covering the past eight centuries, that the LIA stems from the common meteorological practice of describing long-run weather trends by means of moving average series. In this way raw annual series which are essentially stationary, but subject to significant annual fluctuations, are converted into ones characterized by spurious cycles. Figure 1 describes an example of this process in operation; it is based on the well-known reconstruction by Aryan van Engelen, Jan Buisman, and F. IJnsen (2001) of winter temperatures in the Netherlands since the Middle Ages. The first panel, describing the annual data, suggests a stationary series, while the second and third produce a succession of cycles, or what Fagan (2000: 48) describes as a 'climatic seesaw' or 'pendulum of climatic change that rarely paused for more than a generation'. But statistical analysis implies that the LIA is a mirage, an artifact caused by what is known in the literature as the Slutsky effect (Slutsky 1937; Barnett 2006). This is not to deny runs of bad years with disastrous effects on harvests and living standards: the severity of, for example, the mid-1310s, the late 1690s, and 1740-41 is well captured by the Dutch winter series.

[Figure 1 about here]

Where, then, does our rejection of the LIA leave the combination of vivid images invoked by meteorologist Hubert Lamb and historian Emmanuel le Roy Ladurie, and popularized by archaeologist Brian Fagan and others, that link the LIA firmly to key trends and events in European history? We exclude here potential links between the LIA and events as disparate as witch-burning during the Renaissance and the 'general crisis' of the seventeenth century (Behringer 1999; Oster 2004; Zhang *et al.* 2011; compare Tainter 1992: 44-50). Instead, our focus will be on the following well-known images with a direct link to climate change: the demise of grape-growing in southern England in the late medieval era; the vogue for the Dutch winter landscape paintings by Pieter Bruegel the Elder (1525-69) and others; the collapse of Greenland's Viking colony; the periodic 'ice fairs' on London's Thames, ending in 1814; and, as the LIA waned, the contraction of Europe's Nordic and Alpine glaciers. Our review finds that either the evidence of these images is less supportive of a LIA than has been claimed, or that non-meteorological explanations are more persuasive.

1. WINE IN MEDIEVAL ENGLAND

Vintages and wine quality are sensitive to the weather (Chuine *et al.* 2004; Daux *et al.* 2007). Not surprisingly, then, the prospect of further

global warming in the present century has raised questions about its potential impact on wine cultivation and quality (e.g. Ashenfelder and Storchman 2010). The collapse of grape cultivation and wine production in late medieval England is a one of the most resonant images of the LIA (Lamb 1965; Fagan 2000, 2008; Steckel 2005: 243). The area under grapes in pre-Norman England must have been small (Round 1903): the forty-five vineyards recorded in the Domesday Book (1086) were for the most part recently planted, small in size, and catered mainly to the requirements of the Anglo-Norman nobility and to the church. The only yield reported in Domesday refers to the vineyard at Rayleigh, Essex, where six *arpents* yielded twenty *modii* in a good year (*si bene procedit*) (Darby 2007: 372). Assuming that the Domesday *modius* was the same as the Roman measure, this would imply about 30 litres per *arpent*. If the average vineyard had 5 *arpents* (about five acres) under grapes, then this implies a very rough aggregate estimate of about seven thousand litres and, given a population of about 1.6 million at the time, a miniscule per capita consumption.

No more than today, the quality of the output of England's medieval vineyards is unlikely to have matched that of continental vineyards. England's Norman rulers knew their wines, and would not have been content with a mediocre variety that, according to Henry II's chancellor Peter of Blois, had to be drunk 'with closed eyes and tense

jaws' (Renour 1959 1970: 69). Indeed, such was the low quality of English 'wine' that some of it was consumed instead as verjuice (a flavour-enhancing liquid made from unripe white grape varieties: see Willoughby 2010). But lemons, introduced to England in the wake of the Crusades, offered a good substitute for the tart flavour imparted by verjuice, and presumably reduced the demand for the latter.

Before the discovery of the LIA, comparative advantage used to be the traditional explanation given for the decline in English wine production in the wake of Henry II's annexation of the wine-rich regions of Anjou, Poitou, and Gascony in the 1150s (O'Doherty 1824: 6; Renouard (1959) 1970: 67). Although still costly to ship, English imports of Angevin (and, later, Gascon) wine grew steadily thereafter until interrupted by the Hundred Years War (James 1951). The Anglo-Gascon wine trade reached a peak in 1303, when twenty thousand tons were imported [at 232 gallons per ton]; imports were only half that 150 years later at the end of the Hundred Years' War.⁴

Such an interpretation is also consistent with the much higher price of wine relative to beer in England than in France in the Middle Ages. In late thirteenth and early fourteenth-century England a gallon of the

⁴ Review by Sylvia L. Thrupp of *Studies in the Medieval Wine Trade* by Margery Kirkbride James and Elspeth M. Veale in *Speculum*, Vol. 48, No. 2 (Apr., 1973), pp. 369-370.

cheapest wine cost about five times as much as a gallon of the cheapest ale, whereas the ratio for first-quality wines and ales was seven to one. In medieval France, however, beer cost about twice as much as ordinary wine by volume⁵ (compare Dyer 1989: 58, 62; Myers 1972: 192; Unger 2004: 74-77).⁶

2. LANDSCAPE PAINTINGS

Pieter Bruegel's 'The Hunters in the Snow' (1565), one of the masterpieces of the Northern Renaissance, has attained iconic status in accounts of the LIA (e.g. Lamb 1995: 233-34; Fagan 2000: 48). However, most of those who invoke Bruegel's famous oil-on-wood landscape as evidence for the LIA fail to note that it is just one of a cycle of six paintings describing different seasons of the year. Four others survive, including the equally well-known 'The Harvesters', held in New York's Metropolitan

⁵ A quarter litre of beer cost a denier, whereas a *pinte* (roughly 1 litre) of wine cost 1 to 2 deniers

[<http://medieval.mrugala.net/Commerce%20et%20l'argent/Prix%20au%20moyen%20age%20-%20ordre%20chronologique.htm>].

⁶ Lamb also links the decline in the area under grapes in Germany to the LIA, but this hardly squares with the dynamism of German viticulture in the wake of the ravages of the Thirty Years War, even in northern regions such as the Ahr valley (Robinson 2006: 304-08). Perhaps, however, vineyard owners learned to reduce the impact of temperature on yields as in twentieth-century France (Chevet, Lecocq, and Visser 2011).

Museum. Less familiar are 'The Gloomy Day' and 'The Return of the Herd' (both held in the Kunsthistorisches Museum in Vienna) and 'The Hay Harvest' (held in Prague Castle). The five paintings are reproduced in Figure 2. Taken as a group Bruegel's paintings make a less-than-convincing case for a LIA, even if 'Hunters in the Snow' was painted in the wake of what van Engelen, Buisman, and IJnsen (2001) reckon was the coldest winter in the Low Countries between 1435 and 1684.

[Figure 2 about here]

Hendrick Avercamp (1585-1634), another Low Countries painter, was well-known for specializing in lively and joyous if formulaic works, mostly of people enjoying themselves on the ice.⁷ Other painters of such scenes included Gillis Mostaert (1534-98), Lucas van Valckenborch (1530-97), Jacob Grimmer (c. 1525-90), and Pieter Bruegel the Younger (1564/5-1636), although the highly derivative character of Bruegel the Younger's work renders it impossible to link it to contemporary climatic conditions (Burroughs 1981). Note, however, that such snow-and-ice landscapes rarely feature in the work of other better known sixteenth- and

⁷ Robinson (2005: 38) is unsure whether the lack of low cloud and sunshine in Avercamp's landscapes reflected actual climatological conditions or simply an inability to 'portray a high-albedo surface in the sun'.

seventeenth-century Dutch landscape artists such as Aelbert Cuyp (1620-91) or Jan van Goyen (1596-1656), and only one winter landscape by Rembrandt van Rijn (1606-69) survives (Robinson 2005: 38).

In an analysis of over twelve thousand works held in dozens of galleries, and painted between 1400 and 1967, meteorologist Hans Neuberger (1970) believed that he had detected the LIA in changes over time in their cloud patterns and colouring. Dividing the data into three periods—1400-1549, 1550-1849, and 1850-1967—he found that darkness and cloudiness peaked in the middle period. However, patterns in the third period were uncomfortably like those detected in the second, a finding Neuberger attributed to fashion (especially Impressionism) and the atmospheric pollution associated with the Industrial Revolution.

A second study of the link between trends in art and climate by William Burroughs (1981) was more circumspect, and allowed changing tastes a greater role. Burroughs dated the decline of winter landscapes as a theme in Dutch painting from c. 1660, awkward timing from the standpoint of LIA historiography. The part played by fashion in this prompted Burroughs to urge caution in drawing inferences about historical trends from art. More cautious still is a third analysis of the link between the LIA and the varieties of landscape painting by Peter Robinson (2005). Leaving room for both meteorological and cultural interpretations, Robinson concedes that both 'decreasing winter severity'

and the strong influence of Italian styles may explain the lack of snowy landscapes between c. 1420 and the 1560s; that Rembrandt's sole winter landscape is not 'meteorologically completely convincing'; and that Ruisdael's thirty winter landscapes may give a 'somewhat biased' impression of weather conditions in the late seventeenth century (Robinson 2005: 38). Moreover, the precipitous drop in Dutch landscapes painted after c. 1675 owed more to fashion than to changing climate, as the purchasing public increasingly preferred representations of 'sunlit sunny days' (2005: 39). In the late eighteenth and early nineteenth centuries ice scenes sought to reflect Dutch heroism rather than adverse weather, while depictions of sunlight and more realistic cloud formations in the nineteenth century reflected the Romantic movement, and the Impressionist landscapes of the following generation may capture 'short-term synoptic situations' (2005: 39-40). In sum, although trends in early modern landscape art may have been influenced somewhat by climatic change, they can hardly be represented as a faithful impression of it.

3. GREENLAND'S VIKING COLONY AND THE NORDIC COUNTRIES

In accounting for the collapse of Greenland's small Norse colony in the fifteenth century, recent scholarship has de-emphasized the role of climate, and proposed instead several potential competing explanations. They include competition for resources with the indigenous Inuit; the

decline of Norwegian trade in the face of an increasingly powerful German Hanseatic League; the diversion of English fishing vessels from Greenland to Labrador and Newfoundland in the fifteenth century; the undermining of one of the settlers' main resources with the increasing availability from the early fourteenth century of African ivory as a cheaper substitute for walrus ivory; an ill-fated westward migration in the wake of the discovery of Labrador and Newfoundland; and overgrazing by livestock and tree-felling, which resulted in soil erosion (Mackenzie Brown 2000; Lynnerup 1998; Roesdahl 1998; Seaver 2009). The bubonic plague and emigration to Iceland could also have played a role. Iceland, where poor soils and soil management rather than climatic deterioration may have been the main constraints on grain cultivation (Simpson *et al.* 2002), faced its own problems. Even so, the drastic impact of the Black Death on the demands for land and labour in Iceland could have prompted Greenlanders to move there.⁸ Clearly, the number of hypotheses is in inverse proportion to the available evidence. Sheer size mattered too; quite apart from any meteorological threat, in the words of the renowned Danish historian and archaeologist Poul Nørlund, perhaps 'the little colony was too remote to stay permanently strong and healthy. Half a millennium

⁸ The Black Death reached Iceland belatedly in 1402-04, but then killed two-thirds of the population (Thomasson 1977: 410). Whether it ranged as far as Greenland is not known.

it endured. All honour to it for that' (Nørlund (1928) as cited in Lynnerup 1998: 120).

If the LIA led to the collapse of Greenland's Viking colony, then there is a presumption that it should also have had a negative, if less extreme, impact on Europe's colder northern regions. Such an impact is far from clear from demographic trends in those regions between 1500 and 1800. The populations of the Nordic countries—and of Switzerland—would presumably have been more vulnerable to global cooling than those of Europe as a whole (Utterström 1955). However, as Table 1 shows, both regions increased their estimated populations relative to the rest of Europe in the early modern era. That tallies with the claim that in the case of Norway the decline of wheat and rye cultivation from the fourteenth century on owed more to lower German cereal prices than any temperature change: as markets developed Norwegians concentrated more on fish and butter (Miskimin 1975: 59).

[Table 1 about here]

4. CEREAL YIELDS IN ENGLAND:

A corollary of the images described in the previous section is the contraction of wheat cultivation in Europe's uplands and its northern fringes. Fagan (2000), echoing earlier claims by Lamb, argues that

deteriorating climate compromised the cultivation of wheat, always a 'tricky' crop in cooler climates, and reduced the growing season in England by about three weeks by 1500 and by 'as much as five' by the seventeenth century.⁹

This implies that deteriorating climate in the form of a LIA should have left its mark on crop mixes and crop yields in marginal regions. Tillage should have retreated at the expense of pasture and, given its relative sensitivity to cold weather, wheat at the expense of sturdier cereal crops. Ongoing research on output and productivity trends in early modern English agriculture, however, implies that total arable acreage grew between 1380 and 1700, and that the share of wheat in the total cereal acreage held its own. Wheat's share of the arable area fell marginally from 21 per cent of all arable land in 1300 to 18 per cent in 1420, but then reached 21 per cent again in 1600 and 1700. As Figure 3 reports, net wheat yields per acre also held their own relative to those of oats and barley over the same period (Apostolides *et al.* 2008: Tables 4A and 4B). Moreover, Fagan's claim that cooler temperatures led to a shrinking growing season does not sit comfortably with evidence that the number of days worked per household in English agriculture rose by more

⁹ A claim anticipated by Lamb's assertion that 'the growing season was presumably shortened on the long-term average (30-50 years) by about 5 weeks in comparison with the warmest decades of the twentieth century' (1995: 232).

than half between 1450 and 1600 (Apostolides *et al.* 2008: Table 15).

Surely this implies that the economic impact of any LIA on English agriculture was modest at most.

[Figure 3 about here]

5. GLACIERS

Geologist François Matthes (1939) linked his original 'Little Ice Age' to the growth of Sierra Nevadan glaciers following a mid-Holocene thermal maximum, and this prompted others to reconstruct historical glacier lengths (e.g. D'Orefice *et al.* 2000; Oerlemans 2001, 2005). Glacial retreat since the late nineteenth century has become one of the hallmark images of global warming. Glaciers expand and shrink in response to both temperature and snowfall, although in Europe rising temperature rather than reduced precipitation is deemed to be the dominant influence (Ahlmann 1948; Oerlemans 2001). Today the retreat of glaciers in northern Europe and their virtual disappearance in the Pyrenees are linked to global warming. Similarly, Le Roy Ladurie's much-reproduced images of retreating Alpine glaciers are resonant of the LIA, although since they describe the eighteenth century and later they refer only to the *dénouement* of that episode (Le Roy Ladurie 1971). Earlier, comparable

illustrations of the same glaciers would be more telling. In their stead, we have some statistical evidence of the length of some glaciers over a longer period. Figures 4[a]-4[c] describe the computed lengths of three Alpine glaciers at various dates extending back to the sixteenth and seventeenth centuries. Figure 4[b] reveals an increase in the length of Lower Grindelwald glacier in the Bernese Alps between the 1550s and the 1630s, but this gain was cancelled in the following half-century, and the glacier was of roughly as long in the mid-nineteenth century as it had been in the mid-sixteenth. Rhonegletscher, located at the source of the Rhone (Figure 4[c]), lost length between 1600 and 1780, while the Argentière glacier in southeast France (Figure 4[a]) oscillated up and down until the early nineteenth century, when it began a retreat that has continued to the present.¹⁰ The recent reconstruction of fluctuations in the length of the Mer de Glace in the Mont Blanc massif by Nussbaumer, Zumbuehl, and Steiner (2007) implies no sustained change between the early seventeenth and the late nineteenth centuries. Again, Vatnajökull glacier in southeast Iceland hardly grew between the late seventeenth and late nineteenth centuries, though it has shrunk considerably since. However, the pattern on Nigardsbreen glacier in southwestern Norway—a dramatic expansion of 2.8 km between c. 1710 and c. 1740, followed by a

¹⁰ We are grateful for Johannes Oerlemans and Paul Leclercq for the data described in Figure 2. See also Oerlemans 2001.

decline which accelerated from the late-nineteenth century on (Østrem and Haakensen 1993; compare Zemp *et al.* 2011)—has raised questions about the determinants of glacier length (see Figure 3[d]). Atle Nesje and Stein Olaf Dahl (2002; see too Matthews and Briffa 2005) argue that Nigardsbreen's advance was caused by higher winter precipitation rather than by colder summers. The implication that mild and humid winters were responsible for the advance is consistent with other measures of weather at the time, but it means that the link between glacier length and climate change is less straightforward than traditionally assumed in the climate history literature (e.g. Le Roy Ladurie 1971). A recent temperature reconstruction based on available Alpine glacier data implies little change between 1600 and 1750, and then a drop of about 0.1 degree Celsius between 1750 and 1800, followed by a 0.2 degree Celsius rise over the following century (Oerlemans 2005; compare Zemp *et al.* 2011). Overall, such trends are also more consistent with stasis than the dramatic cooling often associated with the LIA.

[Figure 4 about here]

6. LONDON'S FROST FAIRS:

Until 1750 Old London Bridge was the only bridge linking the city with its south bank. Even after the removal of all its shops and houses in 1758-62, it remained a cumbersome structure. The river Thames above the bridge froze over twenty-three times between 1400 and 1814: twice in fifteenth century, five times in the sixteenth, nine times in the seventeenth, six times in the eighteenth, and once in the nineteenth. The freezes gave rise to carnival-like 'frost fairs' on the Thames, some of which lasted for several weeks. Lamb and others have interpreted the seventeenth-century peak in freezes as a product of the LIA (Lamb 1995; Fagan 2000). But note that the likelihood of the river freezing over in given weather conditions varied over time. Frost fairs were much more likely during cold winters in the two centuries after AD1600 than in the preceding or following centuries. Using estimated Central England temperatures as a guide (Manley 1974), between 1660 and 1699 the river froze during four of the fourteen winters when mean temperatures dropped below 2.3 degrees Celsius; in 1700-99 the ratio was five years out of thirteen; in 1800-1899 it was one out of thirteen; and in 1900-80 it was zero out of seven.

Alternatively, the following logit regression runs the occurrence of a frost fair on the Thames (*FROST*) against the Dutch winter temperature series of van Engelen, Buisman, and IJnsen (2001) (*TEMP*)¹¹ and dummy

¹¹ *TEMP* lacks some observations for the early years.

variables for the seventeenth and eighteenth centuries (*C17*, *C18*). *T*-statistics are in parentheses:

$$FROST = 3.19 - 0.10TEMP + 1.54C17 + 1.62C18$$

(-8.87) (-6.71) (3.03) (2.78)

N = 571; Pseudo R² = 0.315; Log Likelihood Ratio = -76.58

The higher probability of frost fairs in the seventeenth and eighteenth centuries, after controlling for temperature, is confirmed.

In 1815 French traveller Louis Simond (1815: II, 262-3; compare Pierce 2001) described London Bridge as follows:

Nothing can be uglier than London bridge; every arch is of a size different from its next neighbour; there are more solid than open parts; it is in fact like a thick wall, pierced with small holes here and there, through which the current, dammed up by this clumsy fabric, rushes with great velocity, and in fact takes a leap, the difference between high and low water being upwards of 15 feet.

What brought the frost fairs on the Thames to an end was not climate warming, but the replacement in 1831 of the medieval twenty-arched London Bridge—plus waterwheels—described by Simond and its big protective platforms by a new five-arched granite bridge that allowed

a much freer flow of water. Figure 5 describes the difference between the old and new bridges. An additional explanation for the increasing frequency of these episodes between 1600 and 1800 may have been the growth of the city. The detritus and silting caused by the increase in London's population from about 0.2 million c. 1600 to 1 million c. 1800 may well have slowed down the river's flow.¹² On the other hand, the employment from 1775 on of convict labour to dredge sand and silt from the river's bottom and so keep the main channel clear may have eased the flow thereafter.

[Figure 5 about here]

¹² According to novelist Tobias Smollet (1771): 'If I would drink water, I must quaff the maukish contents of an open aqueduct, exposed to all manner of defilement; or swallow that which comes from the river Thames, impregnated with all the filth of London and Westminster — Human excrement is the least offensive part of the concrete, which is composed of all the drugs, minerals, and poisons, used in mechanics and manufacture, enriched with the putrefying carcasses of beasts and men; and mixed with the scourings of all the wash-tubs, kennels, and common sewers, within the bills of mortality.' In 1798 agronomist John Middleton, who was prone to exaggeration, claimed that ninety-nine per cent of the contents of privies were being carried into the Thames by sewers (Middleton 1798: 301).

CONCLUSION:

Extreme weather events clearly mattered in the past. Bruce Campbell (2010) has carefully documented their impact for the late medieval period, and Gustav Utterström (1955) and Christian Pfister and Rudolf Brádzil (2006) have done likewise for the 1690s and the 1770s. The famines of 1709-10, 1740-1, 1782-3 and 1816-8 have been linked to severe frosts and volcanic eruptions. Our own statistical analysis points to 1591-1598, 1687-1698, and 1809-1817 as intervals when temperatures were below low average every year (Kelly and Ó Gráda 2011). Yet although such events have been linked to long-run climate shifts, they are not inconsistent with climate stationarity in the centuries in which they occurred. The aim of this paper has been to show that several of the 'stories' that add rhetorical power to the claim for a Little Ice Age have alternative interpretations that do not rest on climate change.¹³ None of this contradicts Le Roy Ladurie's once provocative, if now old-fashioned

¹³ William F. Ruddiman (2007) links falling post-1500 temperatures to the demographic consequences of the Conquista and the consequent reforestation of formerly cultivated land and extraction of carbon dioxide from the atmosphere. The simulations of Robert Dull *et al.* (2010: 3, 10) find that the shock was responsible for 6-25 per cent of LIA-induced cooling. Their results assume modest cooling (-0.1 C), however. Moreover, demographer Massimo Livi Bacci (2008) implies that population decline and resultant reforestation were less drastic than assumed in these studies.

view that 'in the long term the human consequences of climate seem to be slight, perhaps negligible, and certainly difficult to detect' (Le Roy Ladurie 1971).

Finally, we want to emphasize that our scepticism towards the concept of a Little Ice Age defined by significant temperature cooling does not entail a denial of either important changes in climate or the role that human activity may play in these changes. The absence of any major long-term fluctuations in climate during the period from 1200 to 1800 only makes the rise in temperatures during the nineteenth and twentieth centuries stand out as more of a structural rather than a cyclical phenomenon.

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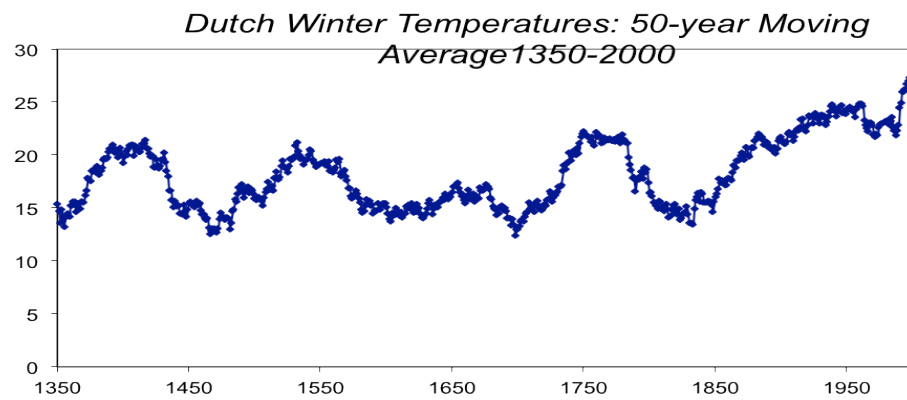
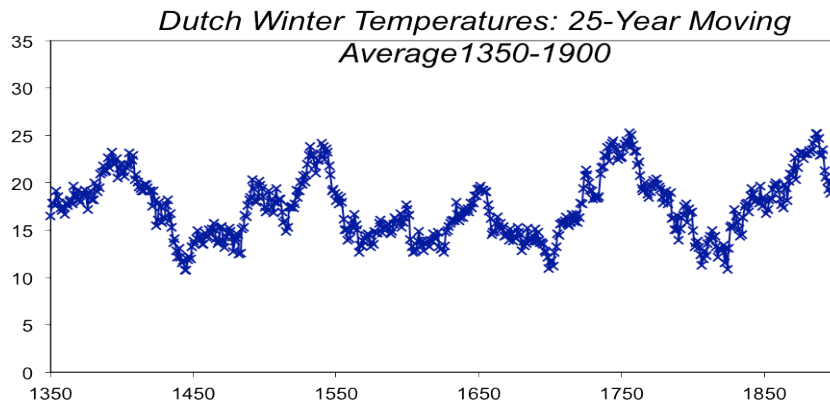
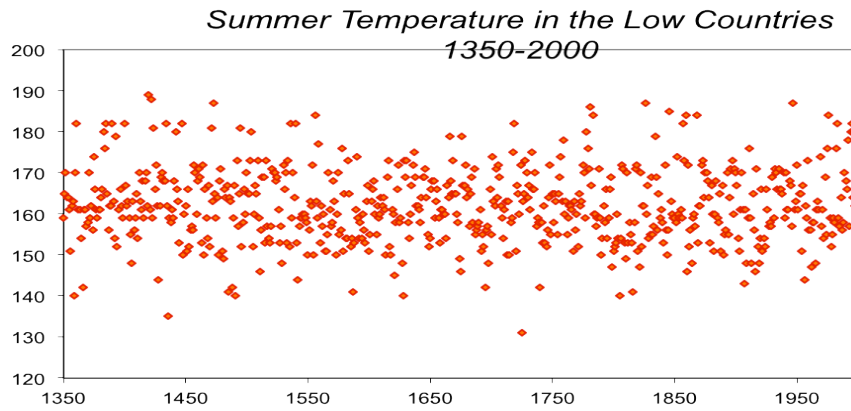
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TABLE 1. Nordic, Swiss, UK, and European Populations 1500-1820 (1,000s)

Country	1500	1600	1700	1820
[1] Finland	300	400	400	1169
[2] Norway	225	400	500	970
[3] Sweden	550	760	1260	2585
[4] Denmark	570	650	700	1155
[5] Switzerland	562	905	1200	1986
[6] Europe	48,192	62,580	68,796	114,571
[1]-[4] as % [6]	3.42	3.53	4.16	5.13
[1]-[5] as % [6]	4.59	4.97	5.90	6.86

Source: derived from data in <http://www.ggd.c.net/maddison/>;
<http://www.tacitus.nu/historical-atlas/population/scandinavia.htm>;
 Mattmueller 1987

Figure 1. Dutch Winter Temperatures 1325-1900



Source: van Engelen, Buisman, and IJnsen (2001)







Figure 2. Pieter Breugel's 'The Months' [1565]

1. The Hunters in the Snow
2. The Gloomy day
3. The Hay Harvest
4. The Harvesters
5. The Return of the Heard

Figure 3. Relative Wheat Yields, 1300/50-1650/1700

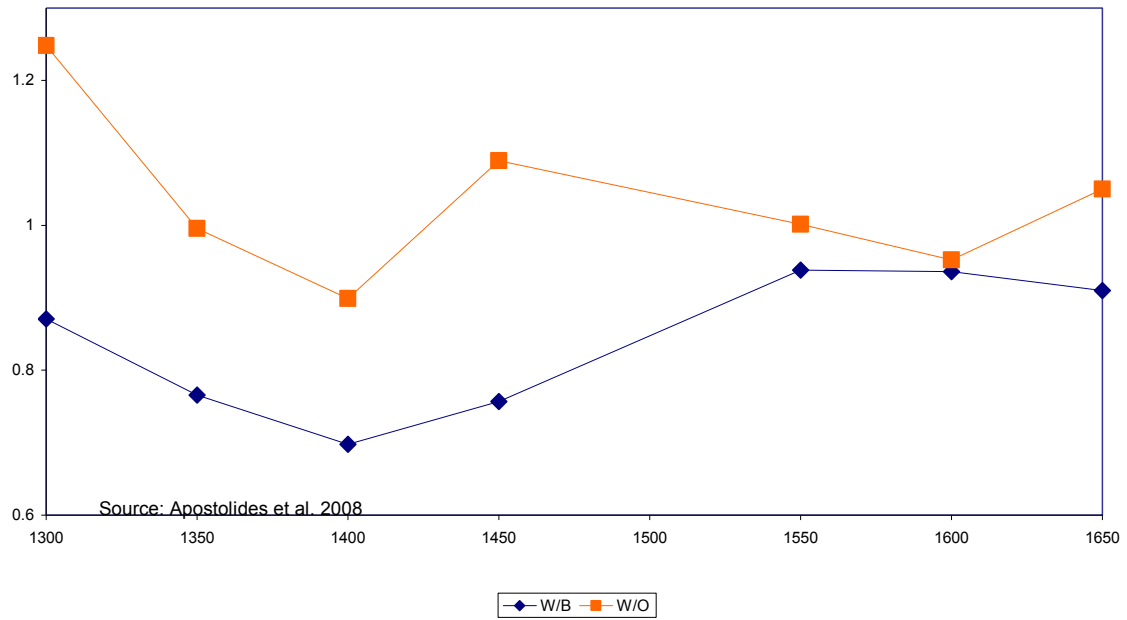
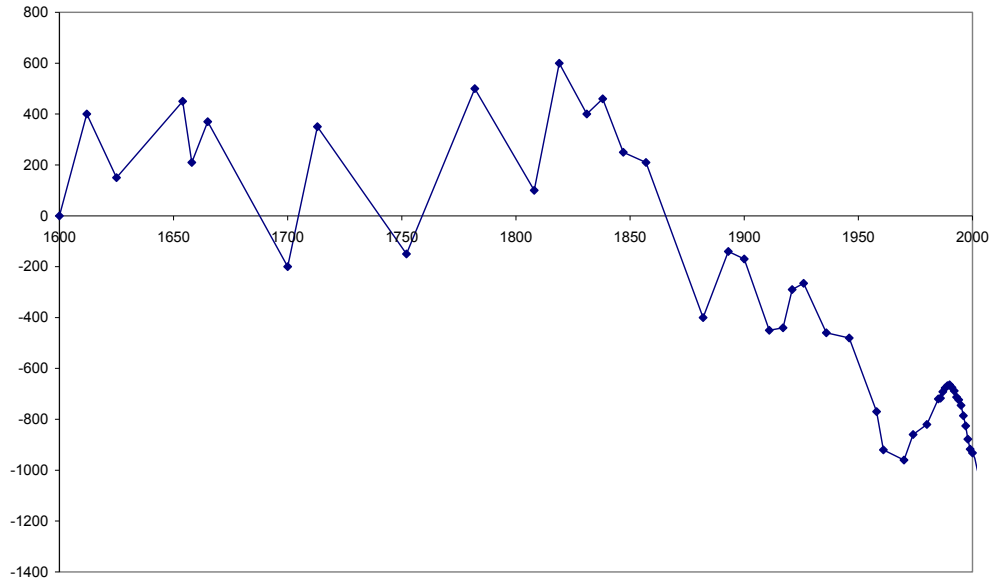


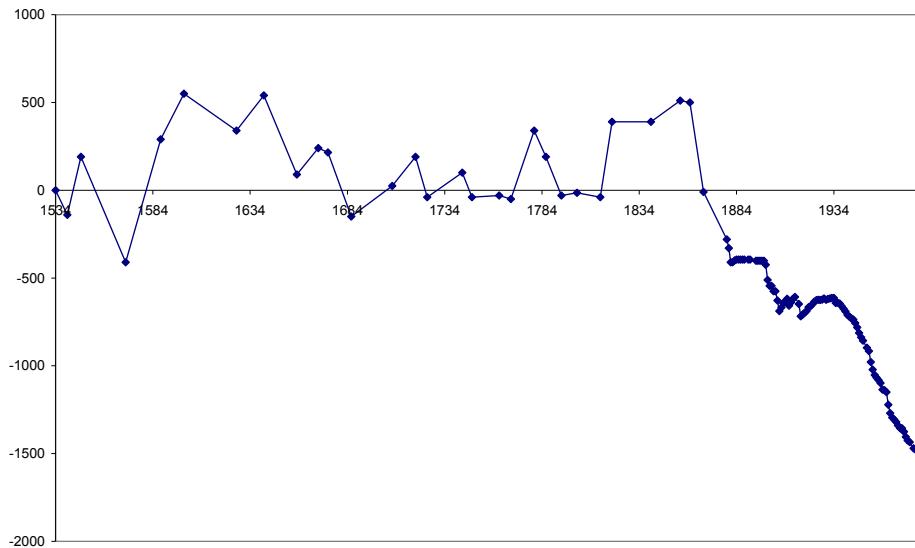
Figure 4. Glacier Lengths, 1500-2000

Argentiere, 1600-2000



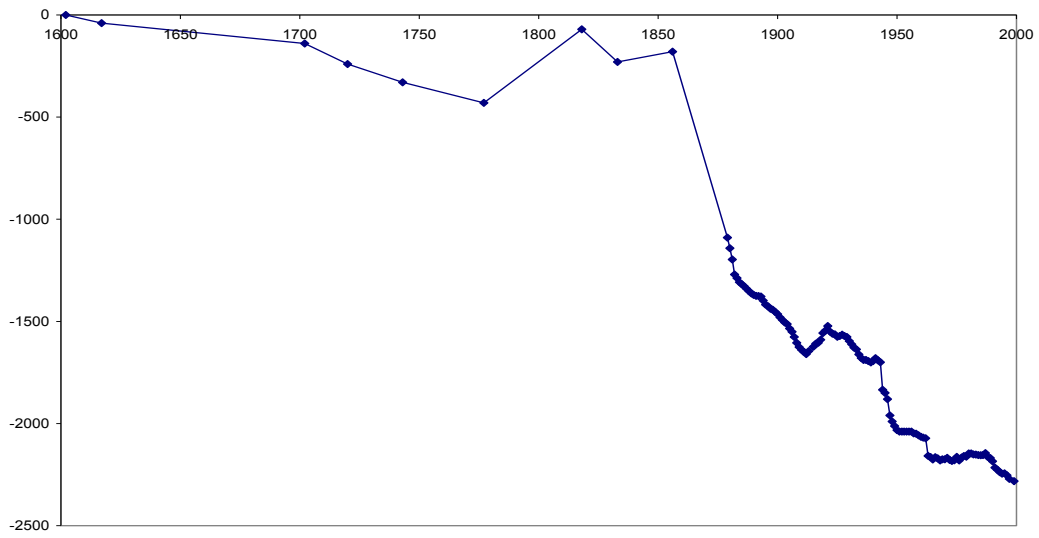
[a] Argentière

U. Grindelwald, 1534-1980



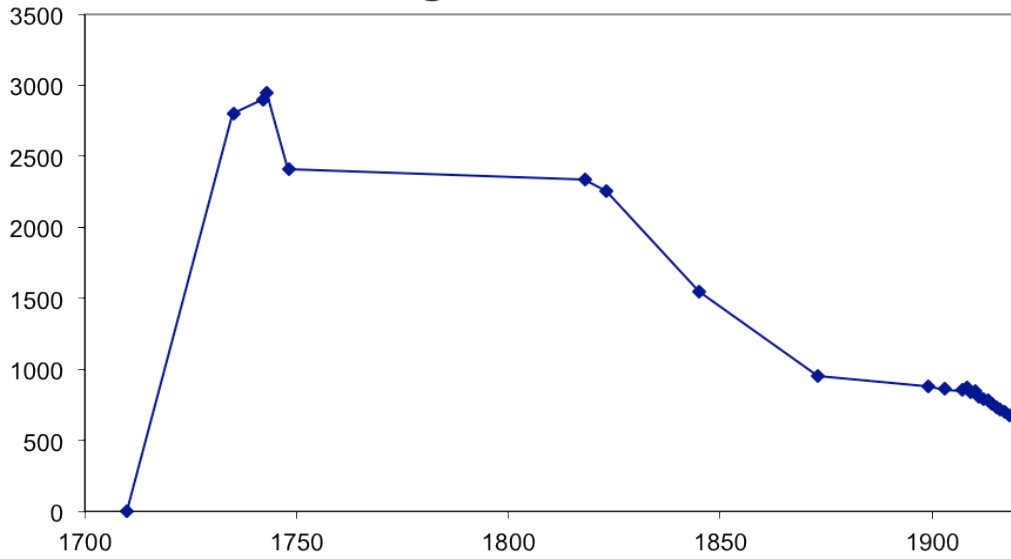
[b] U. Grindelwald

Rhonegletscher 1600-2000



[c] Rhonegletscher

Nigardsbreen 1710-1920



(d) Nigardsbreen



Figure 5. 'Old' and 'New' London Bridge

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