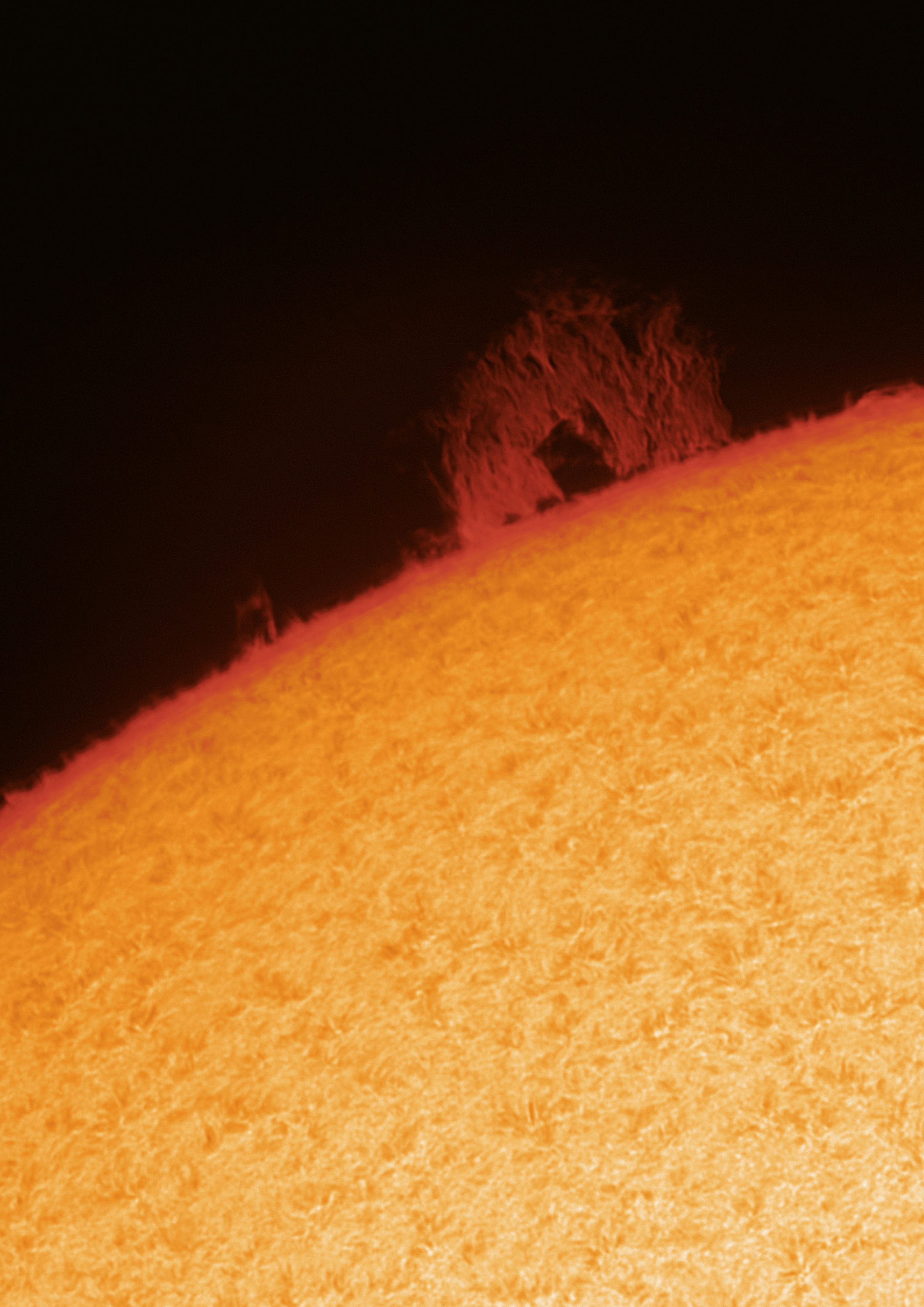
THE NEXT SOLAR CYCLE
And why it matters for climate

David Whitehouse

The Global Warming Policy Foundation
Note 22

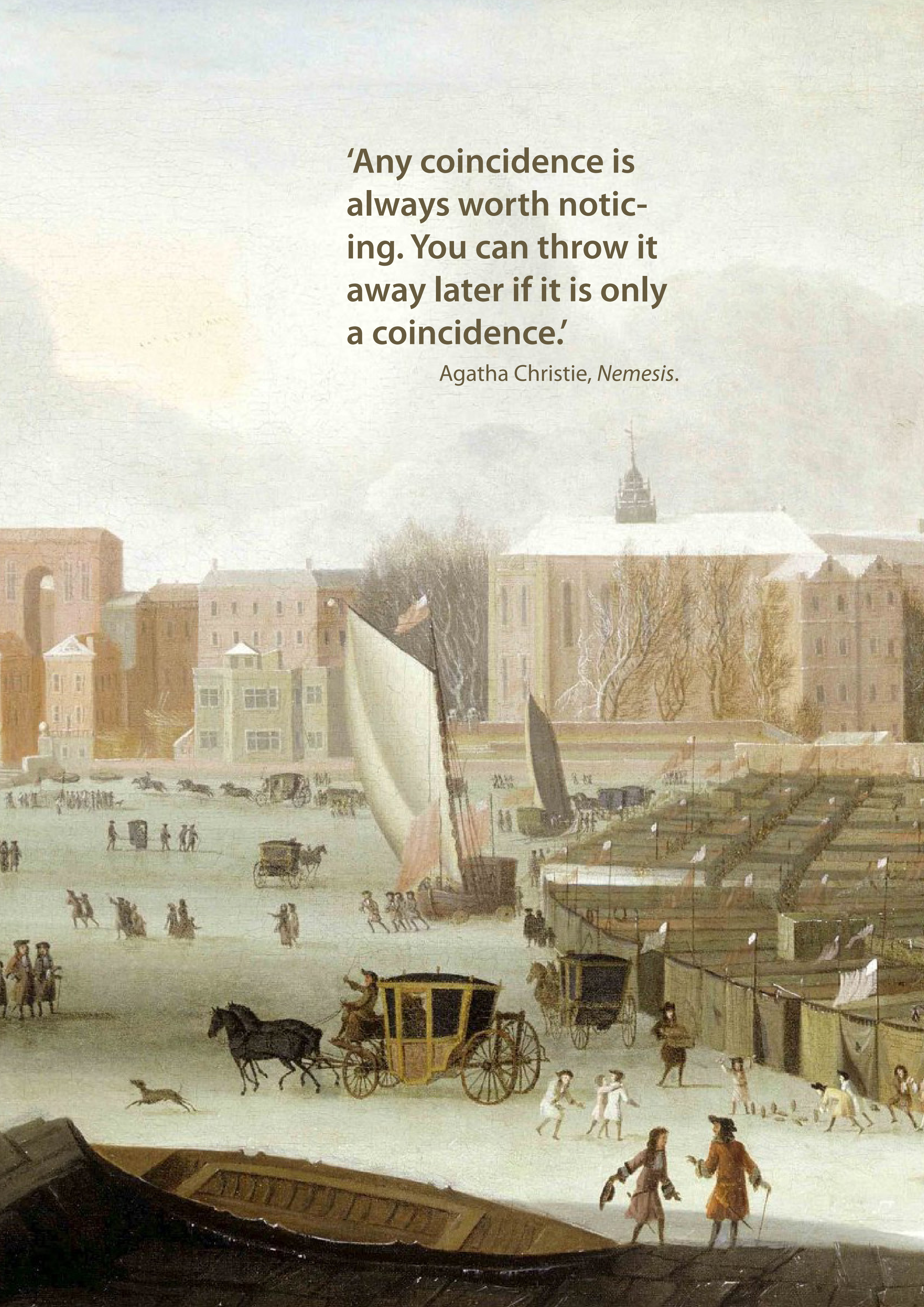


Contents

The Next Solar Cycle and Why it Matters for Climate
David Whitehouse
Note 22, The Global Warming Policy Foundation

‘Any coincidence is always worth noticing. You can throw it away later if it is only a coincidence.’

Agatha Christie, *Nemesis*.

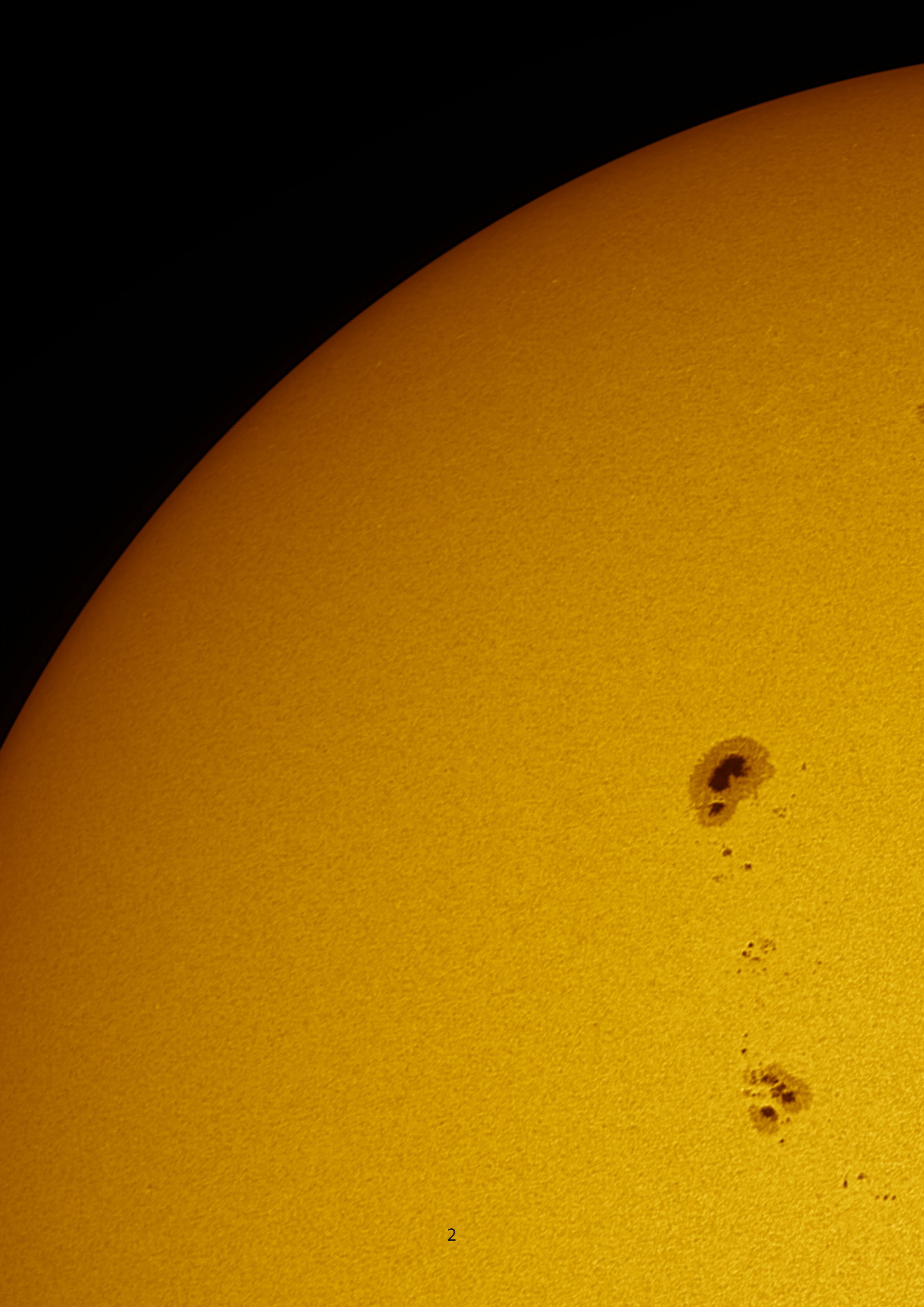


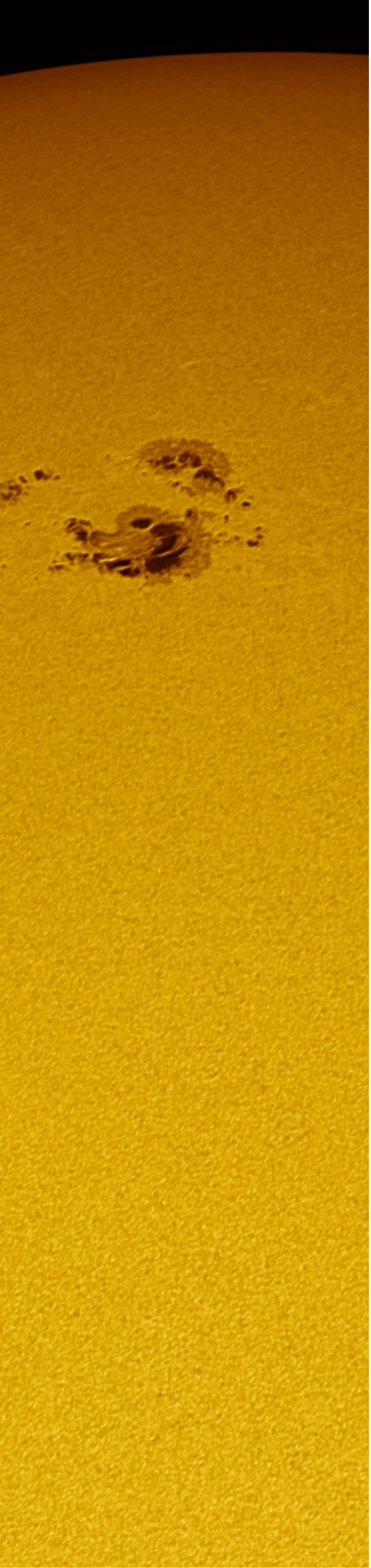
Summary

Predictions for the next solar cycle – Cycle 25 – range from very low activity to stronger than Cycle 24. The National Oceanic and Atmospheric Administration's Solar Cycle Prediction Panel says there is no evidence for another period of very low activity, as in the Maunder Minimum of the late-17th and early-18th century, which could have an important effect on factors that govern the Earth's climate. Nevertheless, there is no consensus and it remains a possibility.

About the author

The science editor of the GWPF, Dr David Whitehouse is a writer, journalist, broadcaster and the author of six critically acclaimed books. He holds a PhD in astrophysics from the Jodrell Bank Radio Observatory. He was the BBC's Science Correspondent and Science Editor of BBC News Online. Among his many awards are the European Internet Journalist of the Year, the first Arthur C Clarke Award and an unprecedented five Netmedia awards. Asteroid 4036 Whitehouse is named after him.





Introduction

2019 was mostly without sunspots. For a long period, the Sun was spot-free for 90% of the time, making the period of minimum activity at the end of Solar Cycle 24[*] and the beginning of Cycle 25 one of the deepest solar minima ever observed.

Understanding the 11-year solar cycle is important, not just for the science of the Sun, but also for appreciating and predicting its influence on Earth and its climate. The Sun is changing its behaviour, and is not acting the same way as it did 50 years ago, when solar cycles were stronger than they are today. How significant is this change? Could the solar cycle behaviour be about to influence the Earth's climate, as some think may have happened 350 years ago? Are we able to make predictions of future solar cycles and be forewarned of their climatic influence? This note discusses some of these issues.

Solar variability

It can be very easy to dismiss the Sun as having far too little variability to have an effect on the Earth's climate. The fluctuations of total solar radiation averaged over the electromagnetic spectrum amount to just 0.1%. However, a much larger variability occurs in the flux of energetic particles and short-wavelength radiation over the 11-year solar cycle, and these changes have effects in the upper regions of the atmosphere. Changes of up to 10% occur in the amount of ultraviolet light leaving the Sun over a solar cycle. It has been suggested that, averaged over the globe, the Earth's surface warms by as much as 0.1°C over the 11-year cycle from solar minimum to solar maximum, and some regions may experience considerably more warming than the average.

Cyclical warming of 0.1° C is important, given the scale of global temperature increase observed this century. Also, any prolonged reduction in solar activity could have decades-long effects on the Earth's temperature. It is important to understand the solar cycle and the predictions of its behaviour in the future.

Some have suggested that the significant variations in climate can only be explained if the influence of the Sun has been underestimated by a factor of about five.[1] Svensmark obtains a similar result derived from temperatures since the Medieval Warm Period, as estimated from boreholes.[2] This implies there would be a decrease of at least 1°C if a new deep solar minimum occurred.

* For convenience, solar cycles are numbered starting in 1755 with Cycle 1. Since 1 July 2015, the original sunspot number data have been replaced by a new entirely revised data series.

The Little Ice Age

There are many ways to estimate the Earth's climate over the past 1000 years or so. Scientists have been ingenious in finding what they term 'proxies' – measurements that in some way reflect the climate. These are an impressive array of phenomena: tree-rings, stalagmites, boreholes, pollen counts, sea sediments, corals, ice cores and mountain glacier deposits. The remarkable thing is that (aside from the past 30 years or so) they generally agree that in the past millennium or so there have been two global climate anomalies: the so-called Little Ice Age (LIA), which stretches from 1300–1900 AD, and the Medieval Warm Period (MWP), from 800–1200 AD. Evidence is found all over the world: in sediments associated with the Indo-China Warm Pool (the largest body of warm water on Earth), in lake sediments in South America, and from radioisotope analysis of shells on the shores of Greenland. These two climatic events are not just European, as was once thought, but more global in nature.

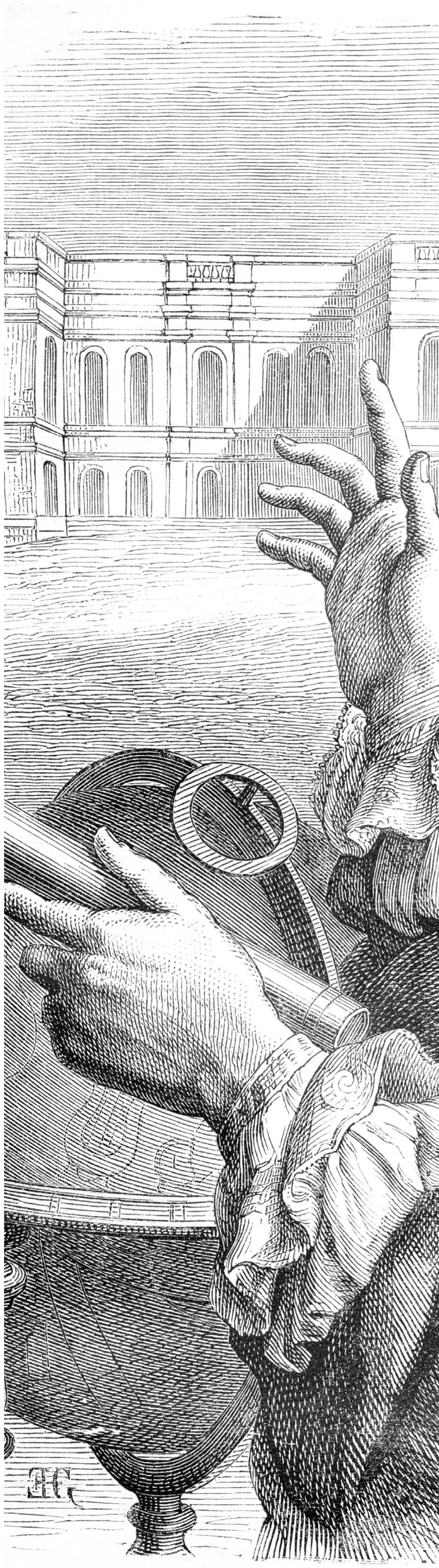
For centuries, many French villages have recorded the date at which the local grapes have ripened. This data shows that, starting in the mid-17th century, harvests began one or two weeks later than before. Cereal production also slumped in the mid-17th century.

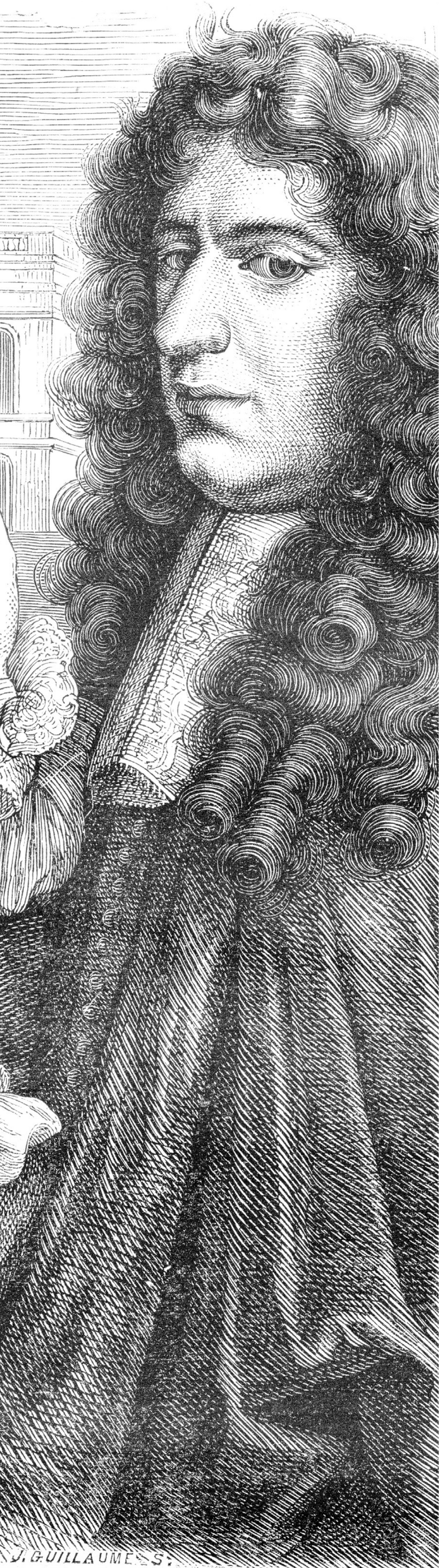
The LIA affected Europe at just the wrong time. In response to the more benign climate of the MWP, Europe's population may have doubled. More people married, and most did so earlier, giving birth to six or seven children despite – or perhaps because – infant mortality was high. But in the mid-17th century, demographic growth stopped, and in some areas fell, in part due to the reduced crop yields. Bread prices doubled and then quintupled. Buying bread now absorbed almost all of a family's income. This in turn caused a collapse in demand for manufactured goods and thus to high unemployment.

High prices and reduced incomes forced many couples in Europe to marry later; the average age of brides rose: they were typically teenagers in the later 16th century, but were putting off getting married until age twenty-seven or twenty-eight in the mid-seventeenth, thus reducing the birth rate. Hunger weakened the population. To paraphrase the English philosopher Thomas Hobbes, writing about political philosophy in 1651, 'the life of man [is] solitary, poor, nasty, brutish, and short'.

Blaming sunspots

During the English Civil War (1642–1651), a preacher told the House of Commons in London, 'these are days of shaking… and this shaking is universal: The Palatinate, Bohemia, Germany, Catalonia, Portugal, Ireland, England.' Later the Tsar of





Muscovy was told, 'The whole world is shaking, and the people are troubled.' There were upheavals in the Ottoman Empire, Portugal, Sicily, Spain, Sweden, and the Ukraine, as well as Brazil, India, and China in the world beyond. Ralph Josselin, an English vicar, wrote, 'I find nothing but confusions.' Josselin looked towards God's inscrutable purpose, but others looked elsewhere. The Italian historian, Majolino Bisaccioni, suggested that the wave of revolutions might be due to the influence of the stars, but Jesuit astronomer Giovanni Battista Riccioli speculated that fluctuations in the number of sunspots might be to blame.

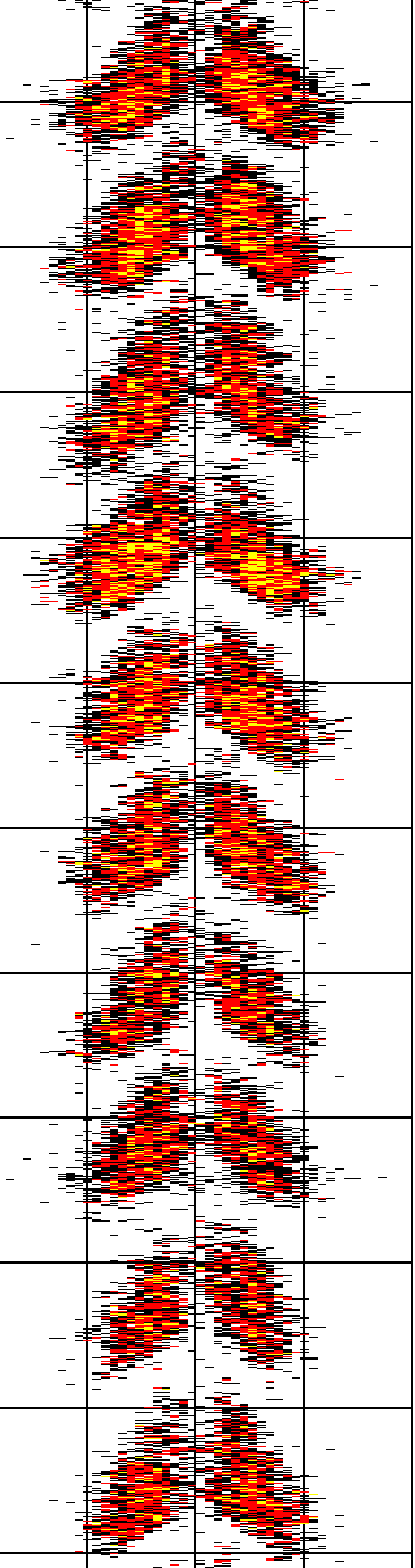
Something was happening to the Sun, and astronomers and philosophers of the time knew it. The early users of telescopes had seen numerous sunspots but, from the 1640s to the early 18th century, they noted with alarm their almost total absence. When Giovanni Cassini, the director of the Paris observatory, saw one in 1671 the *Philosophical Transactions of the Royal Society of London* at once reported it, adding a description of what sunspots were, because the last one had faded away a decade before and readers might have forgotten.

In May 1684, John Flamsteed, the first Astronomer Royal, wrote 'tis near seven and a half years since I saw one before they have been of late so scarce, however frequent in the days of Galileo and Scheiner'.

After an absence of almost a century, sunspots and the northern lights came back suddenly in the second decade of the 18th century. The sun had been in a long period of low activity, but it had now awoken and the particles it was flinging into space struck the Earth's upper atmosphere, causing the rarefied air to light up the night skies of northern Europe and America. The 1780s in particular were a good decade for the northern lights. No one had seen such fine displays in living memory. In addition, two great volcanoes erupted – Laki in Iceland and Asama in Japan – and piled the stratosphere with enough dust to shield the sun and lower global temperatures. For months, the dust meant glorious sunrises and sunsets. It all made a deep impression on the youth of the time. Wordsworth called them 'northern gleams', while Coleridge said they were the 'streamy banners of the north' and 'floating robes of rosy light'.

A sunspot cycle

A few decades later came an important discovery. In 1826, the German amateur astronomer Samuel Heinrich Schwabe (1789–1875), set himself the task of discovering planets inside Mercury's orbit, whose existence had been conjectured for centuries. Like many before him, he realised that his best chance of detecting them was when they transited the Sun, but the main difficulty was the problem of distinguishing



such planets from small sunspots.

He began meticulously recording the position of any sunspot visible on the solar disk on any day the weather would allow. In 1843, after 17 years of observations, he had not found a single intra-mercurial planet but found a cyclic increase and a decrease of the number of sunspots visible on the Sun over time: a solar cycle with a period that he originally estimated to be 10 years.

At first many did not believe him but, in 1852, within a year of the publication of Schwabe's results in a book called *Kosmos*, the Irish astronomer and explorer, Edward Sabine (1788–1883), announced that the sunspot cycle period was the same as that of fluctuations in the Earth's magnetic field, for which reliable data had been accumulated since the mid-1830s. Slowly Schwabe's discovery gained recognition, and others wondered if the cycle could be traced farther in the past using historical observations. Rudolf Wolf (1816–1893) undertook the daunting task of comparing sunspot observations carried out by many different astronomers using various instruments and observing techniques.

The Maunder Minimum

It was the English astronomer at the Royal Observatory, Greenwich, Edward Walter Maunder (1851–1928) who first drew the threads of the mystery of the missing sunspots together. From about 1877, he started measuring sunspot areas and the size of bright patches on the Sun called faculae, collecting data for his 'butterfly diagram', showing the equatorward motion of sunspots during the solar cycle that had been observed by Richard Carrington (1826–1875). It is still a magnificent diagram, based on 9000 photographs of the sun and 5000 separate groups of sunspots over 30 years. It encapsulates so much that is known, and unknown, about the sun.

The question of the missing sunspots fascinated Maunder. Years before, William Herschel (1738–1822), discoverer of Uranus, had noticed something peculiar. There appeared to be a lack of sunspots in five irregular periods: 1650–70, 1676–84, 1686–88,1695–1700 and 1710–13. In 1801, he introduced the idea of a connection between sunspots and climate, when he pointed to periods in the 17th century – ranging from two decades to a few years – when hardly any sunspots had been observed. He pointed out that during those periods the price of wheat had been high, presumably reflecting spells of drought.

For Maunder, the threads came together in the work of an American scientist, Andrew Ellicott Douglass (1867–1962), which linked the missing sunspots with an effect on Earth. Douglass was a remarkable scientist who fell out with his boss Percival Lowell (1855–1916), the great advocator of artificial canals on Mars, because he rightly suspected they were not real. After he had been treated disgracefully by Lowell, he eventually made a new career, almost founding the new science of dendrochronology – the study of tree rings, which were thinner in dry years. He announced some remarkable coincidences between the sunspot cycle and rings in trees after studying beams from old buildings, as well as sequoias and other long-lived trees. He could see evidence for a prolonged dry and cold spell in the 17th century.

This was key evidence for Maunder, and in 1922 he read a letter from Douglass to a meeting of the British Astronomical Association:

> Sequoias show strongly the flattening of the curve from 1670 or 1680 to 1727. Again, taking the evidence as a whole, it seems likely that the sunspot cycle has been operating since 1400 AD with some possible interference for a considerable interval before the end of the 17th century.

Maunder died in 1928 and his work did not receive the attention it deserved; it lay half-hidden, as did the lack of sunspots in the 17th century, for almost 50 years. The value of tree rings for climate study was not firmly established until the 1960s.

In modern times it was the American solar physicist Jack Eddy (1931–2009) who rediscovered it. When Eddy developed the idea the 1600s might have been a period of low solar activity, a colleague told him of the work of Walter Maunder, 100 years before. 'That really piqued my curiosity,' Eddy said.

Eddy faced an uphill battle convincing his colleagues about the reality of what he called the Maunder Minimum,[3] as it relied entirely on accounts from so long ago. But he looked for other evidence and found it. Because he had been trained in astro-geophysics, and knew something of the other ways in which the Sun affects the Earth, he looked hard at historical records of aurorae. He also got acquainted with the Laboratory of Tree Ring Research in Tucson, Arizona. Carbon-14 data from trees clearly showed a pattern of slow growth over the same period, indicating that just when the sunspots had vanished, the Earth had caught a little cold. It was the same with the so-called Spörer Minimum (1460–1550) and the Dalton Minimum (1790–1830).

A magnetic cycle

For many years, scientists have pondered the seeming coincidence of the time the Sun went quiet and the Little Ice Age. Our Sun's stability over billions of years has been essential for life on Earth. However, its shorter-term behaviour, within a solar cycle or across several cycles, is becoming more important for us to understand, given our technological way of life. 'Space weather', and how it alters throughout the solar cycle, has implications for satellite orbits, astronaut health, the state of atmosphere, power transmission and communications. It also has an influence on clouds and climate, subjects of considerable importance.

A major landmark in understanding solar activity came with the work of George Ellery Hale (1868–1938), who first demonstrated the magnetic nature of sunspots and the solar cycle. This led in the 1950s to the development of the idea of the solar dynamo by E. N. Parker (b. 1927).

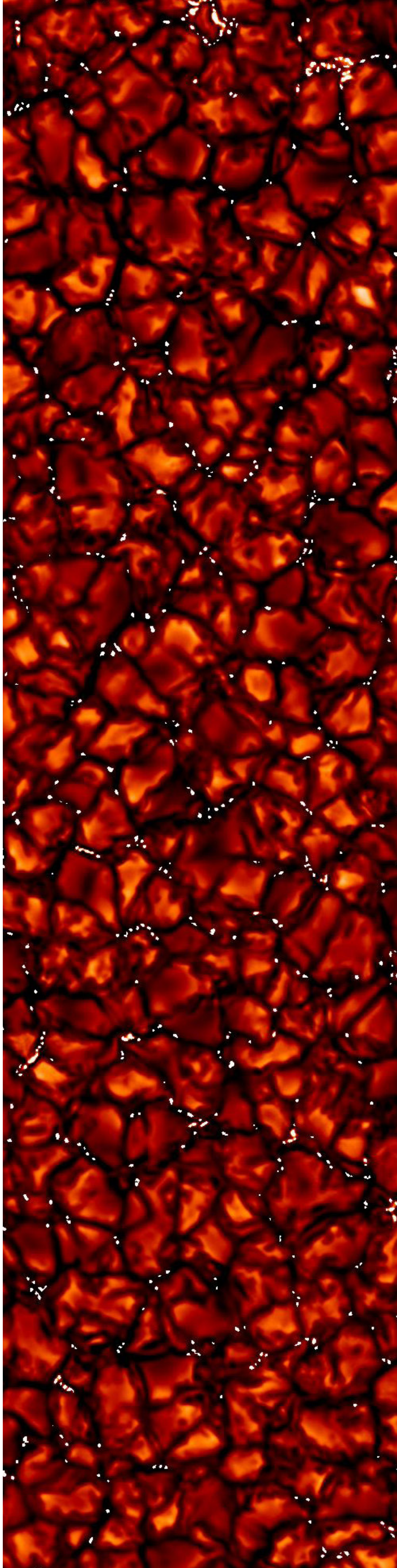
The basic mechanism of the solar cycle is now understood to be the cyclic transformation of north-south to east-west magnetic fields. In fact, these changes are at the root of all phenomena classed as 'solar activity.' We know that a magnetic flux is generated in the Sun's convection zone by the interplay of convection and differential rotation. At the start of a solar cycle, the magnetic field is roughly oriented north–south as it reaches the surface, but it is twisted into an east–west configuration by rotation that is faster at the equator than at higher latitudes.

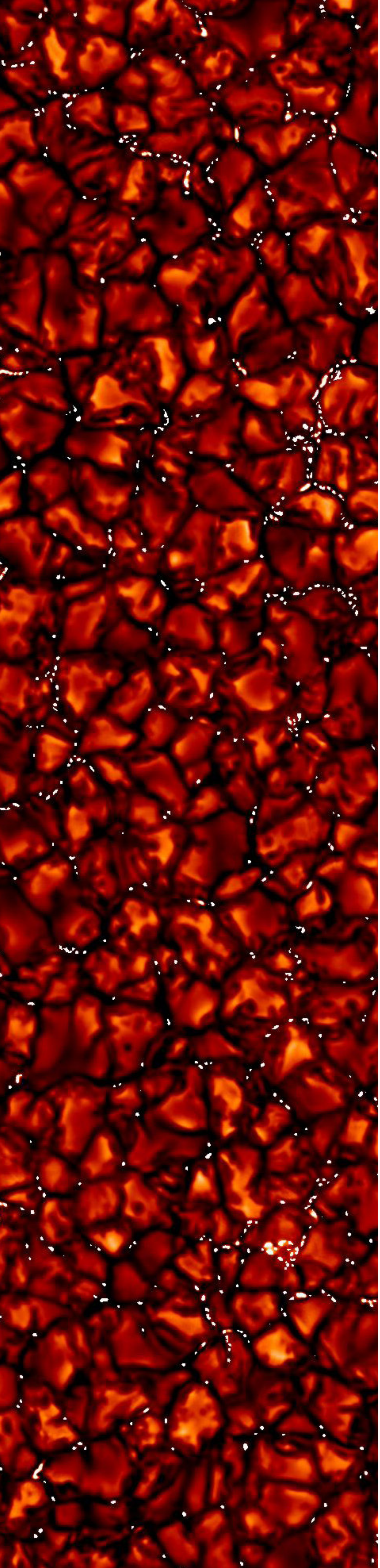
That much is clear, and we have learned much more in recent decades. Indeed, Svalgaard et al. were able to use the insight that cycle strength is linked to the solar poloidal field strength at the solar minimum to successfully predict that Cycle 24 would be very weak. But there remain considerable difficulties. In particular, computer models of the dynamo struggle to reproduce what is observed on the Sun, and the differential rotation in the interior of the Sun, as revealed by the latest advances in helioseismology, seems to be very different from what scientists had expected; they cannot explain how it could produce magnetic fields. Moreover, it has recently been realised that meridional flow is not as simple as previously believed. It was once thought that convection speeds were 100 m/s, but observations suggest that 10 m/s is an upper limit.

As a result, a century after Hale's first observations of the solar magnetic field there is still no consensus about the specifics of the mechanism that generates the Sun's magnetic field; there is no standard model of the solar dynamo.

Cycle 24

Before considering what might happen in the future, it is instructive to look at the predictions made for Cycle 24, the cycle we are currently at the end of. As Cycle 23 wound down in the middle years of the first decade of the 21st century, many solar astrophysicists, watching the Sun to see the first stirrings of Cycle 24, believed they had a good understanding of what causes such cycles. Despite this, predictions for





Cycle 24 varied emormously. One even predicted it would be the strongest cycle ever. In the end it was the weakest cycle in 100 years. The US National Oceanic and Atmospheric Administration (NOAA) predicted it would start in March 2007, then, when it didn't come, they said March 2008, and later had to revise their prediction again. Only Svalgaard produced a prediction that was correct.[4]

The first indication of a new cycle is the appearance of small sunspots at high latitude, usually some 12–20 months before the start of the new cycle. For Cycle 24, they only started to appear in early 2010, making the sunspot minimum between Cycles 23 and 24 unprecedentedly long. Indeed, no living scientist had seen the Sun behave this way: 'This is the lowest we've ever seen. We thought we'd be out of it by now, but we're not,' said Marc Hairston of the University of Texas in 2009. And it's not just the sunspots that are causing concern. There is also the so-called solar wind – streams of particles the Sun pours out – which is at its weakest since records began. In addition, the Sun's magnetic axis is tilted to an unusual degree. 'This is the quietest Sun we've seen in almost a century,' says NASA solar scientist David Hathaway.

Solar Cycle 24 reached its maximum in April 2014, with a peak of 82 sunspots. The Sun's Northern Hemisphere led the sunspot cycle, peaking over two years ahead of the Southern Hemisphere. The relative weakness of Cycle 24 took some astronomers by surprise. There was a cottage industry using the statistics of sunspot data to predict the future, which had not been completely successful. In the past twenty years, and especially armed with the statistics of Cycle 24, it came to be realised that more attention should be paid to the physics of the solar cycle. It is only when physics are included, and not just sunspot statistics, that predictions will be better.

Cycle 25

Our current understanding of the physical processes of global solar dynamics and the solar dynamo that generates the magnetic fields is sketchy at best, and as such we may be producing what will turn out to be unrealistic theoretical and numerical models of the solar cycles.

In April 2019, NOAA predicted that the next 11-year solar cycle is likely to be weak, much like the current one.[5] NOAA's Solar Cycle 25 Prediction Panel predict that Solar Cycle 25 may have a slow start, and they anticipate the solar maximum will occur between 2023 and 2026, with a peak sunspot range of 95–130. This is well below the normal number of sunspots, which is around 140–220 per solar cycle. The panel says it has high confidence that the coming cycle will break the trend of weakening solar activity seen over the past four cycles: 'We expect Solar Cycle 25 will be very similar to Cycle 24: another fairly weak cycle, preceded by a long, deep minimum,' according to the panel's co-chair Lisa Upton. If Cycle 25 is really comparable in size to Cycle 24, it will mean that the steady decline in solar cycle amplitude, seen from Cycles 21–24, has come to an end. Upton believes that it there is 'no indication that we are currently approaching a Maunder-type minimum in solar activity'. Later this year, the panel will release an official Sunspot Number curve, showing the predicted number of sunspots during any given year.

Another prediction for Cycle 25 comes from Sarp and Kilcik.[6] In this study, a nonlinear prediction approach was applied to international sunspot numbers and performance of the model was tested for the last five solar cycles. According to these results, the end of Cycle 24 was expected in February 2020, with a smoothed monthly mean sunspot number of 7.7. The maximum of Cycle 25 is expected at May 2024, with a smoothed monthly mean sunspot number of 119.6. Svalgaard predicts a peak of between 116 and 156.

Looking further ahead than Cycle 25, Ahluwalia looks at the evolution of solar activity over forthcoming sunspot cycles using geomagnetic indices and the solar polar magnetic field intensity.[7] He finds that the baseline of the geomagnetic indices increased monotonically from 1900 to 1986 and declined afterwards, leading him to speculate that there is a cycle, with a basic period of 86 years. He thus predicts an upturn in solar activity in the 2070s. He also points out that solar polar magnetic field intensity has been decreasing systematically for the last three cycles (22–24), as have the sunspot numbers at the cycle peak. Predictions for Cycle 25 are given in Table 1.

Table 1: Predictions for Cycle 25

Author	Sunspot number prediction
Pishkalo[8]	116±2
Miao[9]	121.5±32.9
Labonville[10]	89 (range +29 to −14)
NOAA[5]	95–130
Han[11]	228±40.5
Ahluwalia[12]	7
Dani[13]	159±22.3
Li[14]	168±6.3
Komitov[15]	Same as Cycle 24 or slightly stronger
Bhrowmik[16]	Same as Cycle 24 or slightly stronger
Svalgaard[17]	Between Cycle 24 (116.4) and Cycle 20 (156.6)
NASA[18]	30–50% less than Cycle 24.
Singh[19]	89±9

Coda

In his seminal book *The Internal Constitution of The Stars*, the astronomer Sir Arthur Eddington wrote '…it is reasonable to hope that in a not too distant future we shall be competent to understand so simple a thing as a star.'

Eddington was not saying that the Sun was simple but that, compared to many other structures and phenomena in physics and astronomy, it could be seen as relatively simple. In many cases it is. The generation of nuclear fusion energy at its core, and the transport of that energy outwards, first by radiation and then by convection, has a simplicity and elegance that Eddington would have liked. He would not have regarded the generation of solar activity and its variability as anywhere near elegant or simple.

Notes

1. Scafetta N, Solar and planetary oscillation control on climate change: hind-cast, forecast and a comparison with the CMIP5 GCMs, *Energy and Environment* 2013; 24: 455–496.

2. Svensmark H, *The Sun's Role in Climate Change*, Report 33, The Global Warming Policy Foundation, 2019.

3. Eddy JA, 'The Maunder Minimum', *Science* 1976; 192(4245).

4. Svalgaard L, https://www.leif.org/research/Cycle%2024%20Smallest%20100%20years.pdf, 2005.

5. NOAA Cycle 25 Forecast, https://www.weather.gov/news/190504-sun-activity-in-solar-cycle.

6. Sarp K, 'Nonlinear prediction of Solar Cycle 25', *Proceedings of the International Astronomical Union*, vol. 13, February 2018.

7. Ahluwalia HS, 'Evolution of sunspot number timeline for next several cycles beyond 2016'. *Journal of Atmospheric and Solar-terrestrial Physics*, vol. 176, pp. 57-60, September 2018.

8. Pishkalo MI, 'On polar magnetic field reversal in Solar Cycles 21, 22, 23, and 24', arXiv.org, Aug 2019.

9. Miao WR, 'Prediction verification of solar cycles 18–24 and a preliminary prediction of the maximum amplitude of solar cycle 25 based on Precursor Method', *Research in Astron. Astrophys.*, 2019.

10. Labonville CL, 'A dynamo-based forecast of Solar Cycle 25', *Solar Physics,* June 2019.

11. Han Y, 'A decline phase modeling for the prediction of Solar Cycle 25', *Solar Physics*, August 2019.

12. Ahluwalia HS, 36th International Cosmic Ray Conference, vol. 358, July 2019.

13. Dani S, 'Prediction of maximum amplitude of Solar Cycle 25 using machine learning', *Journal of Physics: Conference Series*, vol. 1231, 2019.

14. Li F, 'Solar cycle characteristics and their application in the prediction of cycle 25', *Journal of Atmospheric and Solar-terrestrial Physics*, vol. 181, p. 110–115, December 2018.

15. Komitov B, 'The 24th solar cycle: Prelyminary analysis and generalizations', *Bulgarian Astronomical Journal*, vol. 30, 2019.

16. Bhrowmik N, 'Prediction of the strength and timing of sunspot cycle 25 reveal decadal-scale space environmental conditions', *Nature Communications*, vol. 9, p. 5209, 2018.

17. Svalgaard L, https://www.leif.org/research/Prediction-of-SC25.pdf.

18. NASA, https://www.nasa.gov/feature/ames/solar-activity-forecast-for-next-decade-favorable-for-exploration.

19. Singh B, 'Prediction of declining solar activity trends during solar cycles 25 and 26 and indication of other solar minimum', *Astrophysics and Space Science*, vol. 364, no. 12, February 2019.

About the Global Warming Policy Foundation

The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while openminded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

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3	Ross McKitrick	An Evidence-based Approach to Pricing CO_2 Emissions
4	Andrew Montford	Climate -- Public Understanding and Policy Implications
5	Andrew Montford	Consensus? What Consensus?
6	Various	The Geological Perspective Of Global Warming: A Debate
7	Michael Kelly	Technology Introductions in the Context of Decarbonisation
8	David Whitehouse	Warming Interruptus: Causes for the Pause
9	Anthony Kelly	Global Warming and the Poor
10	Susan Crockford	Health Polar Bears, Less Than Healthy Science
11	Andrew Montford	Fraud, Bias and Public Relations
12	Harry Wilkinson	UK Shale Developments
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14	Constable and Hughes	Bubble or Babble?
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19	Ray Bates	What Caused Hurricane Lorenzo?
20	Andrew Montford	Reducing Emissions Without Breaking the Bank
21	Andrew Montford	£3 Trillion and Counting: Net Zero and the National Ruin
22	David Whitehouse	The Next Solar Cycle and Why it Matters for Climate

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