The freezing Sun

The glacial scenes from the film, "The Day After Tomorrow" chosen to illustrate this article are certainly a deliberate exaggeration, but by now it is established that long periods of extreme cold on a continental scale can be caused by only rather modest changes in the magnetic activity of the Sun. A new Maunder minimum may have already started.

During recent months, the idea that the prolonged minimum through which our star is going could provoke localized climatic cooling, despite the general warming of the planet, has gained increased support. The idea of a cold period induced by a very quiescent phase of solar activity is not new, but the short historic memory, typical of the human race, means we must frequently dust-off the annals of the past to better understand what could await us in the not too distant future. What better time for a quick analysis

of the so-called Maunder minimum than before a possible repeat performance?
Most people will be familiar with the eleven year sunspots cycle, and the disturbance that every now and again effects radio communications, as protons and alpha particles reduce the ionosphere's capacity to reflect radio waves, interfering with communication even for days. The association between these disturbances and the presence of large active regions on the Sun is well noted and understood, as is the repetition of solar maxima with a mean period of eleven years, measured from minimum to minimum. This cycle was discovered almost 170 years ago by Schwabe and has been confirmed and elaborated repeatedly by other researchers, including Wolf (around 1850) and Waldmeier (1961), until the eighties, when it became clear that the cycle was not stable on time scales of centuries. The work of Eddy, carried out in the seventies and eighties, was fundamental in this regard. He studied the period 1645-1715, for which it was clear that sunspots activity was extremely reduced or even absent, and this had important implications for theories of magnetic field formation at the surface of stars like the Sun.
More specifically, it was necessary to understand if the warming of the planet, already noticed in the last decades of the 20th century, was a direct consequence of increased sunspots numbers with respect to periods when there were few, or rather if there were other factors at play, as in fact turned out to be the case. However, low levels of solar activity do seem to be responsible for climatic changes on continental scales, but to determine this it was necessary to collect as much information as possible on the observations made during the 70 years of the Maunder minimum.
The first researcher to suspect that

sunspots might have been absent during that period was Spörer (1887), who delved into the long series of observations collected by Wolf between 1856 and 1868. Maunder completed the work, between 1890 and 1894, and noted how the disappearance of sunspots coincided with the absence of aurorae. Today we know that the aurorae are caused by sub-atomic particles emitted by the Sun when magnetic energy is released from particularly active regions.

Maunder also pointed out other evidence for the minimum to which his name is given, in particular comments by Cassini (1671) and Flamsteed (1684) who described, with great surprise, the appearance of sunspots.

In one of Flamsteed's notes, found by Maunder, he describes how not a single sunspot had been seen for 10 years, so much so that the only one of 1684 is described repeatedly, in several notes in various publications of the period. The conclusions of Spörer and Maunder were not always unanimously accepted, and most specialists were initially sceptical on the reality of a very prolonged sunspots minimum, interpreting it, rather, as an absence of observations. Further, the few solar cycles completed since their telescopic discovery did not allow long period projections to be made.

But in the seventies Eddy showed that even in the 17th and 18th century there was a certain interest in the observation of sunspots.

Scheiner described, in his Rosa Ursina sive Sol (1626-30) methods for the observation of spots and faculae, and as the best researcher in the field laid down the base for his successors.

Amongst these was Hevelius, who systematically observed the Sun between 1652 and 1685, and Picard, who did the same over an almost identical period, from 1653 to 1685, work continued by La Hire until 1718. The same Flamsteed was a dogged sunspots hunter between 1676 and 1699, finding fewer than 50, many of which very small, when in modern times in a thirty year period we have seen some 40 to 50,000.

There is then some certainty that solar activity started to increase only in 1715. The idea is reinforced by increased reports of aurorae.
On the strength of all this evidence, Eddy published the results of his research in 1976 in *Science*, coining the term "Maunder Minimum". Amongst the arguments discussed were the descriptions of the total solar eclipses between 1645 and 1715, that showed a very reduced, almost absent, corona with respect to that seen previously. Eddy also supposed that if solar activity was really lower in that period then there should have been an increase in the flux of Galactic cosmic radiation leading to an increased production of carbon-14 in the atmosphere. This would have led to higher levels of this isotope in the growth rings of trees, which was indeed confirmed with the analysis of sufficiently old trees. Using the same investigative methods, Eddy also identified an earlier minimum that occurred at the beginning of the 16th century (called the Spörer Minimum) and a conspicuous maximum of solar activity between the 12th and 13th centuries.
If it is true that there has not been any major objection to the arguments of Eddy, as far as a prolonged pause in solar magnetic activity during the Maunder Minimum is concerned, the link to the climate is rather controversial. Those 70 or so years were characterized by very cold weather in Europe, so much so that the Thames froze. It's difficult not to relate the two events: the reduction of active regions on the Sun (fewer large faculae) causes a fall in solar radiation, that causes a cooling of the terrestrial climate, perhaps not in general, but at least on a continental scale.
After the Maunder Minimum both solar activity and the terrestrial temperature started to increase, and what we refer to as global warming is certainly partly due to the trend initiated in 1715.
It's difficult though to discriminate between natural effects on the Earth, solar activity and human factors: how important is each? According to the most recent research, cyclical variations in the Earth's orbit cause major changes in climate over very long time scales, whereas on shorter timescales solar activity is the dominant effect. This can cause brief cold periods, such as that that accompanied the Maunder Minimum, and that that may have already begun, associated with the current prolonged solar minimum. As already mentioned in one of our news items, recent research by Lockwood shows how the recent cold winter, that hit northern Europe particularly hard, was caused by a block of the jet stream that carries temperate air masses from the Atlantic. Comparison of the annual variation of this stream with continental temperature records over the last centuries and with solar activity, clearly shows that when solar activity is weak the Atlantic jet stream becomes less efficient, allowing cold air to flow from the Arctic. The correlation is rather good, good enough that Lockwood found confirmation of his

theory from the recent cold winter, which it predicted. It is interesting to note that in the fifth warmest year globally since records began, Europe has seen the fourteenth coldest winter of the last 160 years. The trend is not encouraging, according to Lockwood the next few winters will be no warmer. If at the continental level there are signs of a possible slowing in global warming, at least as far as the solar component is concerned, this fact should allow a better evaluation of its importance relative to the other factors.
The new element contained in the work of Lockwood is that even a slight variation in a current, either atmospheric or marine (see the North Atlantic oscillation), fed by solar energy, can change the climate at ground level. This can trigger a chain reaction, that, even if often limited to average temperature changes of less than a degree, can cause both economic and social problems. It all depends on the persistence of the cooling, or rather the duration of the current solar minimum: if photospheric activity remains feeble still for some months, we may be at the start of a new Maunder Minimum (that won't be Maunder's anymore but someone else's!), and seeing what caos the occasional eruption of an Icelandic volcano can cause, we should think long and hard about the possible consequences of a slight but prolonged cooling of the climate.

Amelio Frigerio, passionate fan of catastrophic films, works in the field of meteorology and climatology, and does not belittle those astronomical phenomena that may effect the atmosphere. He has long been interested in the Sun-Earth interaction, and discovered this magazine through its series of scientific comics.