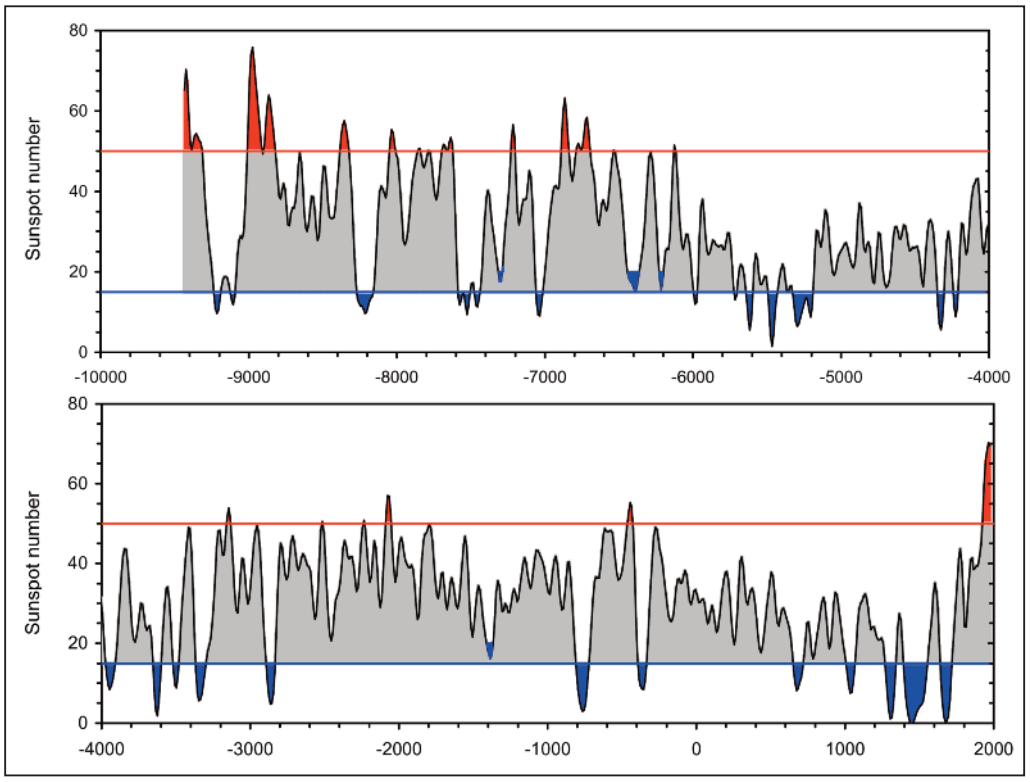
Are we heading for a mini ice age?

The long solar minimum which we are now experiencing seems to herald a repetition of the mini ice age that occurred between the 17th and 18th centuries. Here are the predictions of the researchers.

The climatic consequences of the so-called Maunder Minimum are evident in innumerable works of landscape painters that lived in northern Europe between the 17th and 18th century. To the left, a winter view of Dordrecht (Holland, 1695, by Cornelis Beelt), where we see people ice skating on the completely frozen waters of a lake.

At the end of September 2008, a press release from solar physicists of the NASA Marshall Space Flight Center "alerted" agencies all around the globe.
The news was spread: "*sunspots counts are at their lowest level for 50 years... we are experiencing a deep minimum in the solar cycle*". And further: *"If the Sun continues to be spot free, a glacial freeze could occur on the Earth*". Is this gloomy prophecy of the the American NASA Astronomers the result of an anomalous lack of energetic activity on the visible surface of our star? Could such inactivity have direct consequences for climate, compensating or even inverting the greenhouse effect, taking us from the super-hot of the current epoch to the super-cold? These are the main questions that commentators of the NASA announcement have been asking. An exaggerated outlook? In the recent and distant past of human history alternating periods of high solar activity, accompanied by a warm climate, and periods of very low magnetic activity, accompanied by a freezing climate, have been recorded.
In the graph on page 3 the trend of solar activity over a period of 11,000 years is shown, using both direct and indirect indices of solar activity: the areas in blue and in red correspond to periods of anomalously low and high solar activity respectively, often accompanied by equally anomalous records of climatic behaviour. Perhaps the best known (also because it's the most recent and the only event accompanied by direct solar observations) is the period that historians call the late Baroque era, that is, the second half of the 17th century. Then, a prolonged period of low solar activity, called the Maunder Minimum after the British astronomer that studied it, plunged Europe into a *little ice age*, provoking famine and epidemics that decimated the population. As can be seen in the graph, this period lasted for about 80 years and was centred around 1680. From that epoch the works of various European artists that portrayed the extreme cold of the period became famous. Many other periods of extreme minima further in the past have been well documented, such as that of Spörer, which lasted for 160 years around 1470 and that of Wolf which lasted for 70 years around 1305. Naturally, interspersed with these were long periods of normal activity and also periods of anomalously high activity (al-

Another Dutch winter scene that depicts the freezing climatic conditions experienced during the Maunder Minimum. Jacob van Ruisdael (1628-1682).



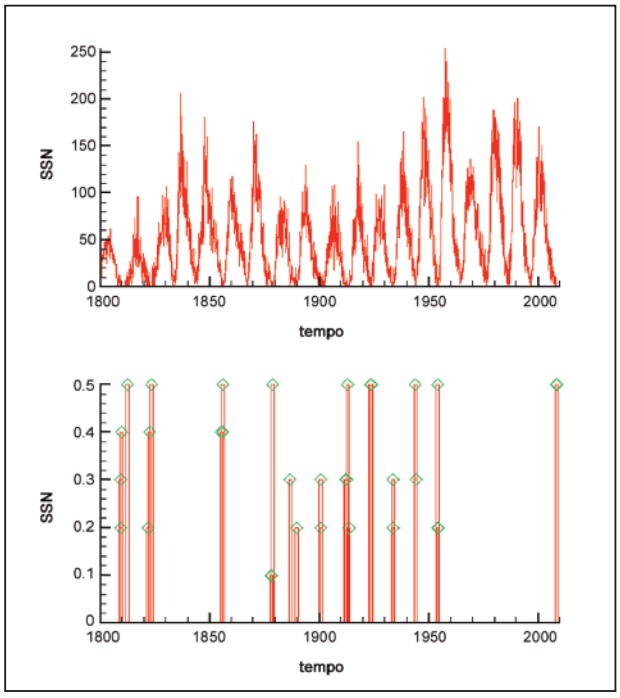
Trend of solar activity during the last 11,000 years, reconstructed also with the help of indirect indicators, such as those derived from dendrochronology and from the concentration of natural cosmogenic isotopes measured in polar ice.

though less frequent than the minima) such as that which we are currently experiencing, that has lasted 80 years (until now) and centred on 1960.
What can we predict about the near future of solar activity and consequent climatic trends, bearing in mind also the anthropic component that is interfering significantly since the last century, with the natural cyclical evolution of the terrestrial climate? The question is very contemporary but extremely complex to answer reliably, also because there is not yet a general consensus on the "weight" that various components, natural on the one hand (solar and volcanic) and man made on the other (greenhouse gasses), have on the final climatic behaviour at the tropospheric level. In favour of a freezing climate, that is at the level of a mini ice age in the near future, are various researchers on the basis of varying arguments: as one example for all, we cite the study of Landscheidt, of the Schroeter Institute for Research in Cycles of Solar Activity (Germany), which, in stark contrast to the findings of the Intergovernmental Panel on Climate Change (IPCC), predicts *"a long period of cold climate with a maximum phase around 2030"*. Landscheidt bases this prediction on the occurrence of minima in the super-solar cycle of Gleissberg, of about 80-90 years, which correlates with the approximately 83 year cycle of the oscillatory motion of the Sun about the centre of mass of the solar system, both of which are well correlated with variations of the the terrestrial surface temperature.
Without entering into the merits of this particular prediction, it is important to underline that the scientific world is anything but unanimous on predictions of warming or cooling of the planet in the next ten years. Usoskin, for example, on the basis of solar activity over an 11,000 year period, concludes that, *"the occurrence of large minima (and maxima) is not the result of long period cyclical variations, but*

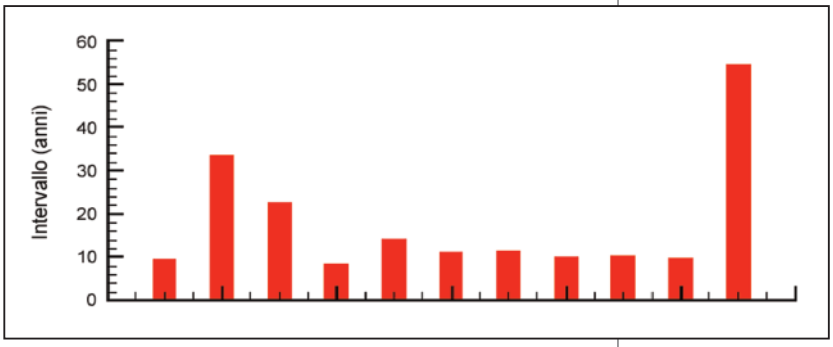
is defined by stochastic and/or chaotic processes", and *"the great minima are of two different types... and this suggests that a large minimum is a particular state of the solar dynamo"*. What we can say is that in recent years an ever larger number of solar researchers support the prediction of low solar activity for our star during the next eleven year cycle.
Let's look now in some more detail at the recent factors that have given rise to the favouring of this conclusion.
The bahaviour of solar activity during the declining phase of cycle 23 has held more than a few surprises, making predictions of the future difficult: the descent phase and minimum have been unexpectedly long; radio fluxes extremely low (F10.7 cm) at 28MHz: 67 SFU (10^{-22} W/m^2), the lowest value of the last 5 solar cycles (-1%); few active regions at high latitudes and with inverted magnetic polarity; moderate activity of regions of the old cycle; reduced total solar irradiation from the last minimum (-0.02%); weak polar magnetic fields (-45 +/- 12%); low velocity of the meridional circulation; reduced pressure and intensity of the solar wind magnetic field (-20%). For brevity we will limit ourselves to discussing sunspots behaviour, the closest to the experience of our readers. To better quantify the present behaviour of the Sun which is still in the minimum phase between cycle 23 and the new cycle 24 (at the time of writing it looks like the minimum has passed and occurred in July/August 2008, and there is now a timid rise of activity in the new cycle) we consider the first graph on page 5. This shows the mean monthly number of sunspots (top) from 1800 to the present day (cycles 5-23), in relation to the lowest recorded minimum values (less than or equal to present values) for the same period (bottom).
As can be seen, the current cycle anomaly isn't so much due to the minimum value reached (July/August 2008), given that similar or lower values have been reached in previous cycles, as to the time interval between the current minima and previous similar ones, going back to the early fifties (minimum between cycles 18 and 19). This interval is, in fact, the longest on record since 1800, as can be seen in the second graph on page 5. This behaviour, together with the properties discussed above, lead us to believe that solar activity is going through a transition period from a regime of relatively high activity to a period of moderate or low activity that may characterize the next solar cycles. More precisely, in some recent studies, such as the work of Jager e Duhau last year, quite believable predictions are made using non-linear methods for solar cycle activity, correlating sunspots variation (seen as an indicator of the toroidal magnetic component of the solar dynamo, the process at the origin of the global magnetic behaviour of the Sun) with the geomagnetic index "*aa*" (seen as an indicator of the polar magnetic compo-

Another painting that clearly illustrates the freezing conditions in northern Europe during the last mini ice age. Aert van der Neer (1603-1677).

nent of the solar dynamo).
Without getting into technical details of the methodology, the authors study long term solar bahaviour via the "topological dynamics" of these parameters: the principal characteristic they find is a "transition state" about which the system oscillates. The main temporal component correlated with this periodic behaviour turns out to be the Gleissberg oscillation (60-110 years). The analysis leads the authors to conclude that: *"the present period of large maxima finished around the year 2000 and we now expect a phase of normal oscillation of duration about one Gleissberg cycle, followed by a period of large minima"*. In other words, these studies conclude that the next three solar cycles could settle to values typical of the Dalton minimum (a moderate minimum at the start of the 1800s), probably followed by a large minimum, such as the Maunder minimum, that could last at least 80 years.
What can be said about the anthropic component of climate change? Are reduced magnetic activity and solar irradiation able to compensate for, or even reverse, the current trend of global terrestrial warming we observe? This is a field of very lively scientific debate and there are many controversies: here we cite just one study by Scafetta and West in 2006, in which they confirm the importance of the solar component in the total energetic balance that influences the climate at the tropospheric level. In particular, the authors find that in the last century (1900-2000) the total solar irradiation has contributed 45-50% to global warming, of which 60% in the period 1900-1950, but only 25-40% in the period 1950-2000. These results seem to confirm the increased importance of the anthropic component in recent climatic changes, but also that the solar component continues to maintain a significant role, greater, in any case, than that assumed in many current



Top: solar cycle trends (cycles 5÷23) from 1800 to today (source: SIDC/Royal Observatory of Belgium). Bottom: lowest recorded minima in solar activity (equal to or less than present values) during the same time interval.



Time intervals (years) between two consecutive minima in the previous graph.

Another Dutch landscape by Aert van der Neer, painted between 1655 and 1660. The great number of paintings with a winter theme is a measure of how common was the freezing of rivers, lakes and coastal bays.

theoretical models (it must be borne in mind that as well as variations in the total solar irradiation, the flux of energetic particles from the solar wind and the cosmic Galactic radiation should also be included as a driver of climate change). These considerations are essential in the development of ever more accurate climate models that make predictions both at the global and regional level.

The previous, and other, analyses on long term solar activity support a picture in which future solar magnetic activity will be between moderate and extremely weak, that could result (anthropic influences permitting) in a *new mini ice age*. As an early warning of this change, in the next months and years, we could already start to experience effects in the form of seasonal average temperatures below normal and generally colder weather throughout the year.

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