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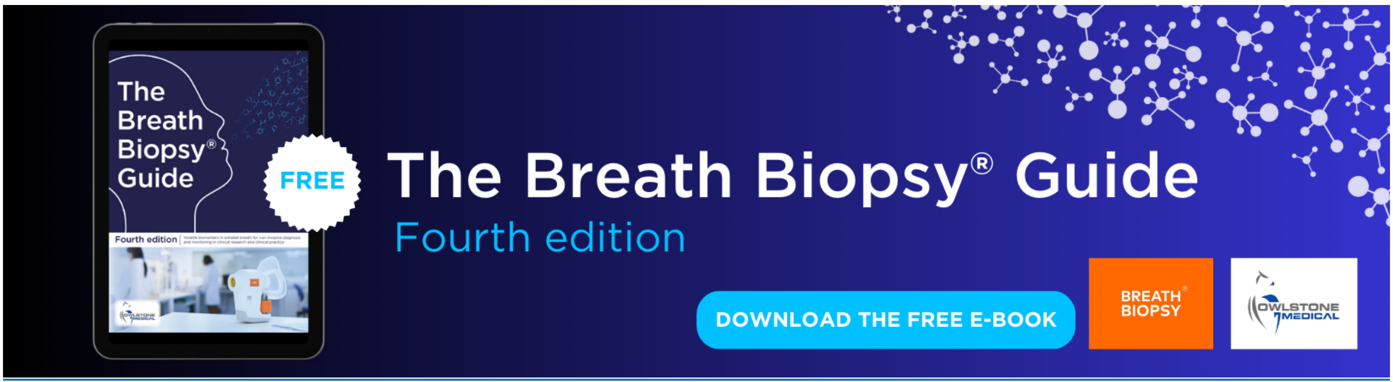

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PERSPECTIVE

Low solar activity is blamed for winter chill over Europe

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Throughout recent centuries, there have been a large number of studies of the relationship between solar activity and various aspects of climate, and yet this question is still not entirely settled. In a recent study, Lockwood *et al* (2010) argue that the occurrence of persistent wintertime blocking events (periods with persistent high sea level pressure over a certain region) over the eastern Atlantic, and hence chilly winters over northern Europe, are linked to low solar activity. Is this then a breakthrough in our understanding of our climate?

The Wolf sunspot number, which dates back to Galileo's invention of the telescope in the 17th century, represents one of our longest geophysical data records. Galileo was also involved in building the first barometers and thermometers around that period. Hence, the 17th century represents the start of instrumental measurements of weather and climate, and there are indeed historical records of speculations or studies on the link between changes in the sun and conditions on Earth dating from that time (Helland-Hansen and Nansen 1920).

One notorious problem with many previous studies was that relationships established over the calibration interval subsequently broke down. There was a period in the mid-20th century when little work was done on solar activity and climate, but solar activity was considered a real forcing factor before 1920. With the advent of frontal theory, orbital forcing theory, and stronger awareness of the implications of enhanced greenhouse gas concentrations, the support for solar forcing seemed to have diminished in the climatology community by the mid-20th century (Monin 1972). But non-stationary relationships, the chaotic character of climate, weak effects, and lack of a physical understanding behind such a link, can also explain the low support for solar forcing at that time.

For a long time, it was not established whether more sunspots meant a brighter or dimmer sun (the answer is brighter), and then the direct effect from changes in the solar brightness (0.1%) was estimated to be too low to explain the temperature changes on Earth. The solar influence on changes in the global mean temperature has so far been found to be weak (Lean 2010, Benestad and Schmidt 2009). The important difference between recent and early studies is, however, that the latter lacked a theoretical framework based on physical mechanisms.

Now we understand that stratospheric conditions vary, and are affected by chemical reactions as well as the absorption of UV light. Furthermore, we know that such variations affect temperature profiles, wave propagations, and winds (Schindell *et al* 2001). Lean (2010) and Haigh (2003) provide nice reviews of recent progress on solar-terrestrial relationships, although questions regarding the quality of the oldest solar data records are still unanswered (Benestad 2005). All these studies still rely on empirical data analysis.

Much of the focus of the recent work has been on climate variation on global scales. The recent paper by Lockwood *et al* (2010) represents current progress, albeit that they emphasize that the relationship they identify has a regional rather than global character. Indeed, they stress that a change in the global mean temperature should not be confused with regional and seasonal means. The physical picture they provide is plausible, yet empirical relationships between solar activity and any of the indices describing the north Atlantic oscillation, the Arctic oscillation or the polar vortex are regarded as weak.

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My impression is nevertheless that the explanation provided by the Lockwood *et al* (2010) study reflects real aspects of our climate, especially if the effect is asymmetric. They argue that solar-induced changes in the stratosphere in turn affect the occurrence of persistent wintertime blocking. But one comprehensive, definite, consistent, and convincing documentation of the entire chain causality is still not in place, due to the lack of long-term high-quality observations from remote sensing platforms. It is nevertheless well known that the temperature in northern Europe is strongly affected by atmospheric circulation. Crooks and Gray (2005) have identified a solar response in a number of atmospheric variables, and Labitske (1987), Labitske and Loon (1988) and Salby and Callagan (2000) provide convincing analyses suggesting that the zonal winds in the stratosphere are influenced by solar activity. Furthermore, Baldwin and Dunkerton (2001) provide a tentative link between the stratosphere and the troposphere. The results of Lockwood *et al* (2010) fit in with earlier work (Barriopedro *et al* 2008) and provide further evidence to support the current thinking on solar-terrestrial links. Thus, it is an example of incremental scientific progress rather than a breakthrough or a paradigm shift.

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