Space Weather on Human Physiopathology

Subjects: Pathology
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While the exact nature and mechanisms of action still need to be better understood, some adverse effects of space weather have been related to the occurrence of magnetic storms. Triggered by solar emissions, it takes about one to three days for the effects to be felt on Earth, thus leaving enough time for a warning to be issued. Such a warning system is already in place, for instance in aviation and other human endeavors. Applications in the healthcare system have also emerged. Precisely because non-photic environmental cycles are notoriously wobbly, mapping their non-stationary characteristics in specific frequency ranges as they change over time may lay the foundation to research which features of space weather may influence what aspects of human physio-pathology. Mapping long-term periodicities shared between the environment and biota will facilitate making connections between the presence of non-photic cycles in the cosmos, how they may be affecting the ionosphere and influence weather on Earth, and how these changes can impact agriculture, nutrition, the presence of pathogens, and overall human health.

Keywords: heart rate variability ; space weather ; long cycles

1. Introduction

There is merit of long-term forecasts of both meteorological conditions and space weather. Mapping long-term periodicities can play an important role in this respect. Time series analysis can also help explain how climatic changes may be affected by space weather[1]. Non-photic cycles related to space weather have periods, among others, of about a week, about 0.42 year (solar flares), about 1.3 years (solar wind speed), and about 11, 22, and 35 years (sunspots). All have documented counterparts in human physiology and pathology[2][3], albeit shared periodicities do not necessarily imply the existence of a causal relation.

Assessing influences of space weather on human physiology and pathology often relies on correlations between the socio-biological variable and the environment. One serious pitfall of such an approach is the disregard for periodicities characterizing both biology and inanimate nature, many of them shared between the two systems. Correlations notoriously lead to spurious results in the presence of rhythms, as the correlation coefficient is largely dependent on the phase difference of a given periodic component between the two variables. Indeed, if two variables share the same periodicity and are in phase, the correlation will be positive, but if they are opposite in phase, the correlation will be negative, and if they are in quadrature, the correlation will be near zero. In the presence of cycles, methods other than the Pearson product-moment correlation are advocated. Cross-spectra and coherence spectra are one option, as are superposed epoch analysis and the remove-and-replace approach.

An influence from solar activity has been known for a long time. Data reported in 1922 already showed an increase in symptoms of patients on days with versus days without sunspots[4]. Whether considering all or only severe symptoms (such as those related to the heart and vessels, liver, kidney, and nervous system), their incidence is higher on days with sunspots (p < 0.001). Using more rigorous methods than the Pearson product-moment correlation, some of the periodicities shared by the environment and biology are briefly reviewed, with a focus on the cardiovascular system.

2. Circaseptans

The very young, the elderly, and otherwise vulnerable individuals are thought to be particularly affected by space weather. The nonlinearly estimated period of the prominent about-weekly (circaseptan) variation of blood pressure and heart rate of newborns, synchronized by the time of birth (development) rather than by the day of the week (social influence)[5], correlates with the circaseptan period of the local geomagnetic activity index obtained during matching spans[6]. Adults also display a more prominent about-weekly variation in heart rate when a circaseptan component characterizes the rate of change in sunspot areas, as detected using a remove-and-replace approach[7]. In both cases, results were modulated by an about 10.5-year component similar to the solar activity cycle. Similarly, a circaseptan component characterizes mortality from myocardial infarction, as shown in the Republic of Georgia during the span from 1980 to 1982 when solar activity was high and the interplanetary magnetic field underwent an about-weekly variation, but not during the span from 1984 to 1987 when solar activity was down, as were circaseptans in the interplanetary field[8].

3. Circatrigintans

The Sun, composed of a gaseous plasma, rotates with different periods at different latitudes. Julius Bartels' Number is the serial count that numbers the apparent rotations of the Sun as viewed from Earth, used to track certain recurring or shifting patterns of solar activity. In this system, each rotation has a length of exactly 27 days, close to the synodic Carrington rotation rate, starting on 8 February 1832 as day one.

Traute and Bernhard Düll collected and evaluated meteorological data and thousands of death certificates between 1 January 1928 and 31 December 1932; they stacked the mortality data over 68 consecutive 27-day solar rotation cycles along the scale of Bartels' Numbers. They could thus align patterns in the daily incidence of mortality from different causes with those of relative sunspot numbers and worldwide magnetic characters, assessed separately for each day of the 27-day Bartels' cycle after stacking. They documented clear 27-day patterns for all-cause mortality as well as for death attributed to nervous and sensory system diseases, suicides, diseases of blood circulation, and from respiratory diseases. Compared to peak mortality from cardiovascular diseases, deaths attributed to nervous and sensory system diseases peaked earlier and deaths from respiratory diseases peaked later. Possible differential effects of space and/or Earth weather were thus shown with respect to suicide and other deaths associated with the nervous and sensory systems versus death from cardiac or respiratory disease as well as overall death by differences in the phase of a common 27-day cycle characterizing these mortality patterns[9].

4. Cis-Half-Year

The cis-half-year with a period of about 0.42 year, which characterizes solar flares, is also modulated by an about 10.5-year cycle, as found in a 40-year record of around-the-clock self-measurements of heart rate by a clinically healthy man[10]. In these data, a spectral analysis revealed the presence of prominent yearly and half-yearly components in addition to a less prominent about 0.42-year component. Fitting this 3-component model to data in a 4-year interval progressively displaced by a 0.2-year increment, the 0.42-year component is detected with statistical significance only when the total solar flares index is high. Its amplitude follows an about 10.5-year pattern lagging that of solar flares. A cis-half-year also modulates circulating melatonin, sampled around the clock serially-independently from each of 172 clinically healthy individuals examined between October 1992 and December 1995[11]. It is further a prominent spectral peak in transverse data on uric acid and in the incidence of sudden cardiac deaths in several geographic locations[12].

5. Transyear

Beyond a cis-half-year, uric acid, and the incidence of sudden cardiac deaths are also characterized by a transyear, with a period of about 1.3 years, detected in data on solar wind speed. A transyear is present in all 43 longitudinal records of blood pressure and heart rate available for analysis thus far[13]. It also characterizes the daily incidence of mortality from myocardial infarction in Minnesota during the span from 1968 to 1996 and the incidence of suicides in Minnesota during the span from 1968 to 2002. In addition to solar wind speed, cosmic rays (in Chicago), solar magnetism, Wolf numbers, coronal index, Kp, aa, and Dst also showed an about 1.3-year periodicity.

6. Multidecadals

The about 10.5-year component characterizing mortality from myocardial infarction in Minnesota during the span from 1968 to 1996 accounts for 5% excess deaths during years of maximal solar activity compared to years of minimal solar activity[14]. Circadecadal cycles have been documented in individual records of physiological variables (blood pressure, heart rate, and heart rate variability), in bacterial sectoring, and organismic resistance (gauged by a 15-year record of urinary excretion of 17-ketosteroids by a clinically healthy man). These numerical near-matches of biota with the solar activity cycle, organized as a sequence of events (gauged by the relative phase relations of biological extrema following extrema in solar activity) are only hints, but additional results from spectral coherence and superposed epoch analysis suggest an association with natural physical environmental factors for several aspects of human morphology, physiology, and pathology[15]. A histogram summarizing the best-fitting periods (determined by nonlinear least squares) in the low-frequency spectral region for all longitudinal records available to us for analysis showed a clear peak around 10.5 years[16]. In Ladakh, where studies monitored the cardiovascular health of populations living at different altitudes, systolic blood pressure was found to follow an about 10.5-year cycle similar to that of solar activity in the population as a whole[17]. There, a strong magnetic storm was followed by catastrophic floods. This event, in turn, was associated with drastic changes in blood pressure and mood (Figure 1).

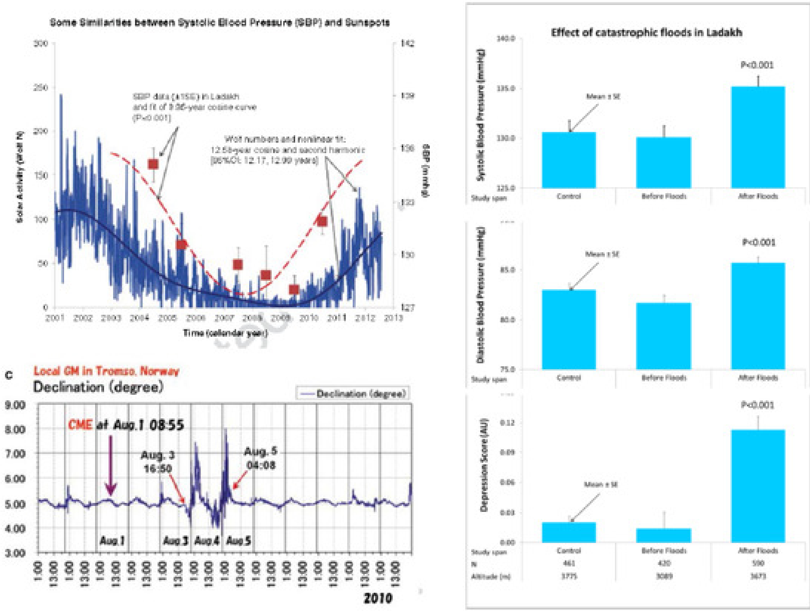

Figure 1. Systolic blood pressure follows an about 11-year cycle similar to that of solar activity in Ladakh (top left). A strong magnetic storm was followed by catastrophic floods in Ladakh (bottom left), where studies monitored the cardiovascular health of populations living at different altitudes. This event was associated with drastic changes in blood pressure and mood (right). © Halberg Chronobiology Center

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