Solar Forcing of Changes in Atmospheric Circulation, Earth's Rotation and Climate

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Abstract: Cross analysis of available historical series of solar wind turbulence, atmospheric circulation, Earth's rotation and sea surface temperature, when smoothed from the secular trend and periods shorter than 23 years, allowed a cascade climatological model to be set up that integrates the Sun-atmosphere-Earth system as a simple unit and ties solar corpuscular output to sea surface temperature through atmospheric circulation and the Earth's rotation. An increase in solar corpuscular activity causes a deceleration of zonal atmospheric circulation which, like a torque, causes a deceleration of the Earth's rotation that, in turn, causes a decrease in sea surface temperature. Application of this holistic model allows us to predict a gradual decline in global warming starting from the current decade.

Keywords: *aa* Index, zonal wind, Earth's rotation, sea surface temperature.

INTRODUCTION

There has been an explosive increase in the use of General Circulation Models (GCM) to forecast the increase in the Earth's mean temperature caused by anthropogenic atmospheric CO_2. This requires powerful computers that provide the solutions to a complex set of partial differential equations, strongly combined non-linearly, involving large quantities of input data. For modeling the atmosphere-ocean system, simplification often means leaving out available information or ignoring known or suspected processes. In the past, this practice was forced upon modelers by the limits of computational power. However, the greatly increased speed and decreased cost of computer technology has made it possible to construct models of far greater complexity than most scientists imagined only a few years ago. The GCMs are currently subordinated to the value of their complexity, which is interpreted as evidence for the increased sophistication and hence of the presumed realism of the models. However, the more complex a model, the harder it is to refute. So we face a paradox: the closer a model comes to a full representation of the complex atmosphere-ocean system, the harder it is to evaluate. There is a trade-off between representation and evaluation. To overcome such a paradox, a new methodological approach is here proposed: the scientist must have the courage to come out from inside the investigated phenomenon and investigate the same phenomenon from the outside. This means that the results provided by the GCM reductionist approach must be also compared with those provided by a holistic one that relates among themselves solar and terrestrial phenomena [1], investigates the phenomenon in its totality and drastically reduces the number of degrees of freedom similarly to those used in celestial mechanics in which the operative forces are described by a small number of equations involving variables that are determined with a high degree of accuracy. In this paper, we present a holistic model that relates solar forcing to sea surface air temperature through atmospheric circulation and length of day. We suggest here that the solar electromagnetic and corpuscular radiations show similarities in temporal behavior but can generate completely different terrestrial mechanisms. The electromagnetic flux is estimated to be stronger than the corpuscular one by orders of magnitude, but the spatial inhomogeneity of the latter becomes an important factor in affecting tropospheric processes.

COLLECTION OF DATA

We analyzed the historical annual series of:

a) External geomagnetic activity *aa* (nT) (interval: 1868–2007) which measures the turbulence of the solar wind in the ecliptic plane [2]. The *aa* index is the average of the K index measured at two antipodal stations, which is why it is recognized as a high-quality consistent record of global geomagnetic activity. The Greenwich and Melbourne observatories worked simultaneously until the end of 1967, when they were superseded by the Abinger-Hartland and Toolangi observatories, respectively. The properties, advantages and behavior of *aa* were comprehensively studied [3,4]. The yearly data of *aa*, reported in Fig. (**1**), are available from the web site: ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/RELATED_INDICES/AA_INDEX/Aa_month/

b) Sea level atmospheric pressure P (hPa) provided by the Climatic Research Unit, University of East Anglia (interval: 1873–2003). Coverage over the Northern Hemisphere is much denser than over the Southern

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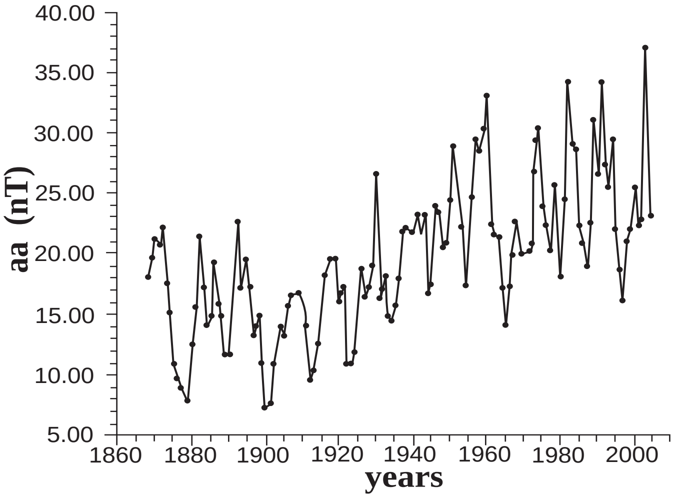

Fig. (1). Time plot of yearly values of geomagnetic activity *aa*.

Hemisphere. Hence the analysis in this study has been confined to the Northern Hemisphere. The yearly data are available at a spatial resolution of 5° latitude by 10° longitude, from the web site: http://www.cru.uea.ac.uk/cru/data/atmosphericpressure/. To obtain a simple measure of the yearly zonal wind, the difference in pressure ZI (hPa) between the entire 35°N and 55°N circles [5] was computed. The yearly data of ZI are reported in Fig. (**2**). The prevailing flow can be derived easily from just its sign and magnitude; the advantage of such a computation is that it integrates the complex distribution of pressure over an entire hemisphere into a single figure, thus facilitating comparison between various situations.

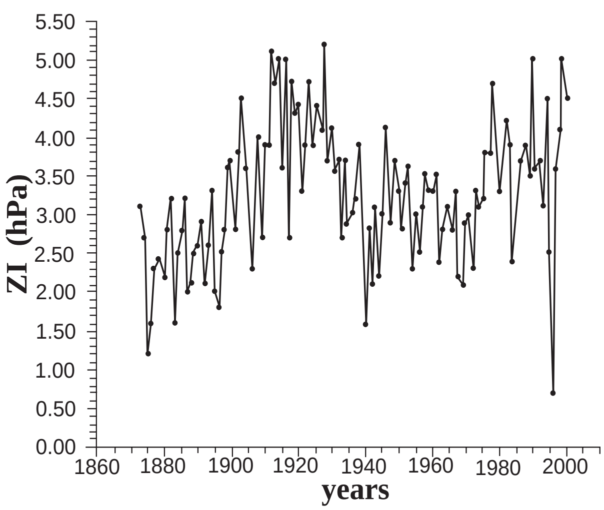

Fig. (2). Time plot of yearly values of zonal atmospheric circulation *ZI*.

c) The Earth's rotation rate as normally measured by means of the length of day LOD (ms). This represents the difference between the astronomical length of day and the standard length (interval: 1850–2007) [6]. The yearly data of LOD, reported in Fig. (**3**), are available from the web site: http://www.iers.org/iers/earth/ rotation/ ut1LOD/table3.html.

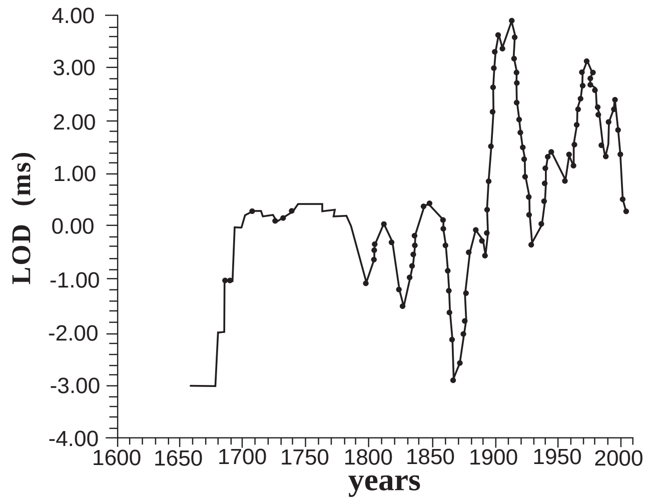

Fig. (3). Time plot of yearly values of length of day *LOD*.

d) Sea surface temperature SST (°C) provided by the Climatic Research Unit, University of East Anglia (interval: 1850–2007) as anomalies from the period with the best coverage (1961–1990) [7,8]. The coverage is much denser over the Northern Hemisphere than the Southern Hemisphere, hence the analysis here has been confined to the Northern Hemisphere. The yearly data of SST, reported in Fig. (**4**), are available from the web site: http://www.cru.uea.ac.uk/cru/data/temperature/.

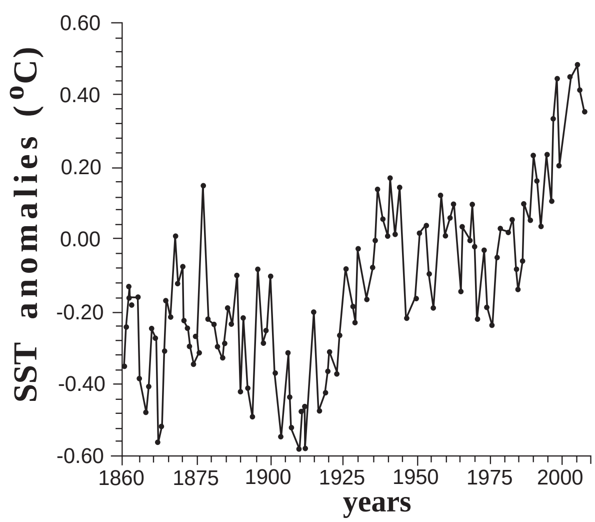

Fig. (4). Time plot of yearly values of sea surface temperature *SST*.

SST can be reasonably considered as the true thermometer of atmosphere-ocean system owing to largest thermal capacity of the ocean; SST behaves like a natural filter that eliminates all the short time variations that normally affect air temperature. Moreover, 70% of the Earth's surface is occupied by ocean for which SST is more representative than air temperature that is measured on land stations often biased by the environment on which they operate. Thus SST reflects the sum of all different air temperature measures.

METHODOLOGY AND ANALYSIS

It is well known that the geomagnetic activity *aa* shows large fluctuations at 11 and 22 years and a significant increasing secular trend [3,4,9,10]. The geomagnetic solar activity is available only from 1868 and, for this, to investigate long-term behavior of geomagnetic solar activity, it is advantageous to smooth the yearly available series by using a 23-yr running mean and normalize them with respect to their mean linear relation. In fact, the variations in the residuals can be subjected to more accurate low-frequency spectral analysis than when they are biased by high-frequency waves and by non-cyclic variation. The aim of this paper is to investigate the geomagnetic forcing of sea surface temperature through the atmospheric circulation and Earth's rotation rate. It is useful to recall that the major role for *aa* and ZI is that of a buffer zone, where energy inputs from external sources are accumulated, modulated and transmitted. Observable effects from this type of process would more than likely be cumulative and would affect long-term climatological changes rather than induce sudden changes in tropospheric weather. Thus application of Riemann integrals to detrended yearly values of *aa* and ZI, i.e., the sequential summation of the detrended *aa* and ZI, provides the values of Iaa and IZI that are also indicative of solar wind and of zonal wind speed.

RESULTS

Table **1** shows, for each pair of investigated variables, the phase lag in correspondence of which the highest value of correlation coefficient is found to be confident at a level greater than 95% [10]. For visual inspection, all the time plots of the investigated yearly variables are normalized to a mean of zero and to a standard deviation of 1. Fig. (**5**) shows the time plot of yearly values of Iaa and IZI, detrended and smoothed according to the 23-yr running mean; Iaa and IZI appear strictly inversely related with a correlation coefficient of -0.97 when Iaa is shifted ahead by 5 years. This indicates that an increase in solar wind speed causes a decrease in zonal atmospheric circulation after 5 years. Fig. (**6**) shows the time plot of yearly values of IZI and LOD, detrended and smoothed according to the 23-yr running mean; IZI and LOD appear strictly inversely related with a correlation coefficient of -0.87 when IZI is shifted ahead by 4 years. This indicates that a decrease in zonal atmospheric circulation causes a deceleration of the Earth's rotation after 4 years. Fig. (**7**) shows the time plot of yearly values of LOD and SST, detrended and smoothed according to the 23-yr running mean; LOD appears to modulate SST inversely with a correlation coefficient of -0.98 when IZI is shifted ahead by 4 years. This indicates that an increase in day length causes a decrease in sea surface temperature after 4 years.

DISCUSSION

Most scientists believe that anthropogenic CO_2 is producing an enhanced greenhouse effect and that the Earth's mean temperature will increase in the next 100 years, being convinced disciples of the mathematical reductionism that provides forecasting starting from ever smaller boxes containing portions of atmosphere and ocean and where non-linear algorithms are forced to operate. In this regard it is useful to consider the numerous failures of GCM models when compelled to operate at seasonal scale! This reductionist approach is misguided since the model will never be able to be correctly evaluated. To overcome such a paradox, we followed a holistic approach that analyses the Sun, atmospheric circulation, Earth's rotation and sea temperature as a single unit (ut unum sint): the

Table 1. Phase Lag (in Years) in Correspondence of which the Highest Correlation Coefficient R is Obtained, for Each Pair of Investigated Variables, Together with the Relative Confidence Level

Pair of Variables	Phase Lag (Years)	R	Confidence Level
Iaa <==> IZI	5	-0.97	99%
IZI <==> LOD	6	-0.87	95%
LOD <==> SST	4	-0.97	99%

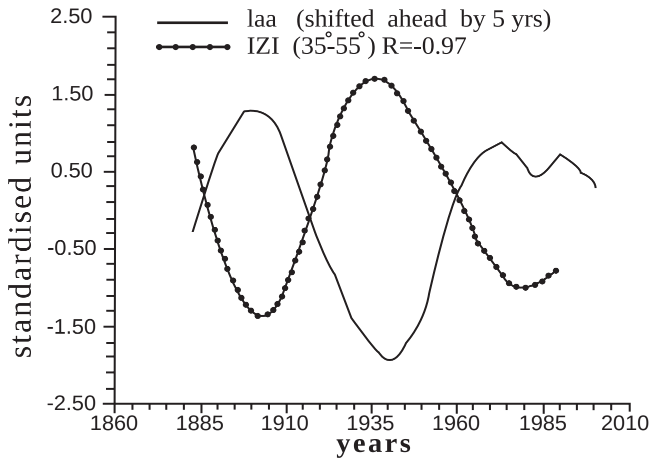

Fig. (5). Time plot of yearly values, detrended and smoothed according to the 23-yr running mean, of Iaa and IZI.

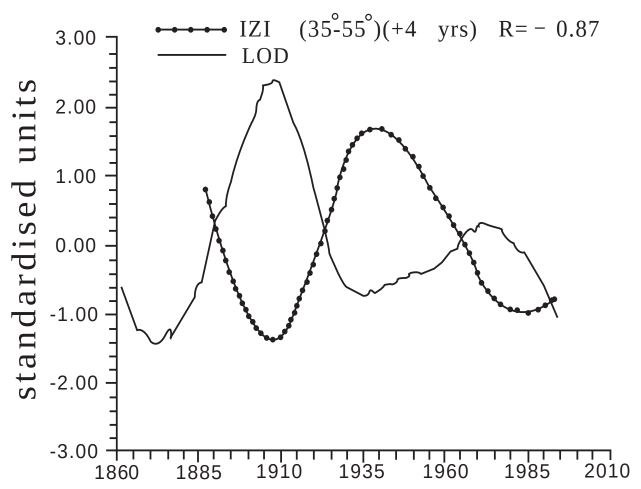

Fig. (6). Time plot of yearly values, detrended and smoothed according to the 23-yr running mean, of IZI and LOD.

arrival on the Earth of fronts of hydrodynamic shock waves during epochs of strong ejection of particles from Sun gives rise to a squeezing of the Earth's magnetosphere and to a deceleration of zonal atmospheric circulation which, like a torque, causes the Earth's rotation to decelerate which, in turn, causes a decrease in sea temperature. Under this holistic approach, the turbulence of solar wind and the zonal atmospheric wind behave cumulatively rather than instantaneously, where energy inputs are first conveniently accumulated and then transmitted. The zonal wind speed (IZI), obtained by integrating ZI with the Riemann algorithm, allows classification of the relative dominance of either zonal or meridional transport of the air masses on the Northern hemispheric scale: the meridional circulation is found to be dominant in 1885-1915 and 1960-2000 epochs and the zonal circulation in 1915-1960 and current epochs (Fig. **5**). There is almost an equilibrium between zonal and meridional components of air flow. Strong zonal circulations with a contracted circumpolar vortex are related to an increase in SST while weak zonal westerly circulations or, equivalently, strong meridional circulations with meandering or cellular patterns with an expanded circumpolar vortex are related to a decrease in SST; zonal epochs correspond to periods of global warming and meridional ones to periods of global cooling [11,12]. Day length (LOD) behaves as a variable that integrates all its inner dynamics related to the different cellular tropospheric circulations. For example, the behavior of IZI computed between 85°N and 55°N provides similar results to those obtained between 35°N and 55°N but with a different phase lag in respect to Iaa. It is worth noting the excellent antisymmetry between the time behavior of LOD and SST (Fig. **7**); when LOD has a maximum, SST has a minimum of similar amplitude after 4 years and so on. This holistic approach can supply the estimate of future climate since changes in LOD can be reasonably used as indicators of future changes in SST. Recently, a large 60-year cycle in LOD was identified at a confidence level greater than 99% [13]; provided that the observed past correlation between LOD and SST continues in the future, the identified 60-yr cycle provides a possible decline in SST starting from 2005 and the recent data seem to support such a result (Fig. **4**).

CONCLUSIONS

A large portion of global warming was explained here in terms of turbulence of solar wind, atmospheric circulation and Earth's rotation. At the basis of the model is the idea of a coherent whole with an integrated mechanism encompassing the whole Earth-atmosphere-Sun system. If the solar corpuscular activity behaves in the same way in the future as in the past, its 60-yr cycle might suggest a forecast estimate for a gradual cooling of the Earth's atmosphere in this decade.

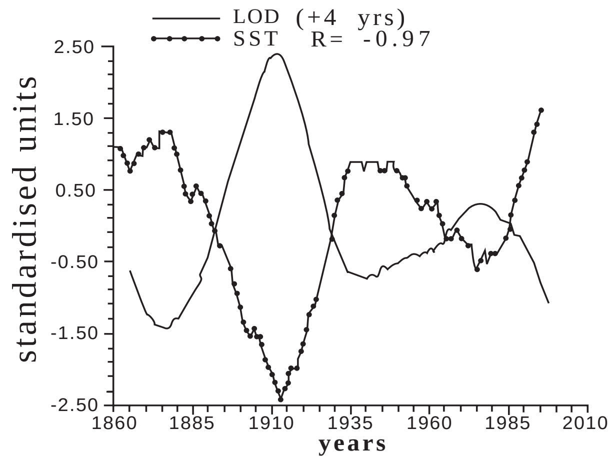

Fig. (7). Time plot of yearly values, detrended and smoothed according to the 23-yr running mean, of LOD and SST.

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