Comments on: "11-year cycle in Schumann resonance data as observed in Antarctica" by Nickolaenko et al. (2015)

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Abstract Recent interpretation by Nickolaenko et al. (2015) of Schumann resonance observations in Antarctica is reviewed. Evidence from the literature suggests that certain aspects of these interpretations are flawed. Alternative interpretations are offered.

Keywords: Schumann resonance, Antarctica

Introduction

In a recent article in this journal, Nickolaenko et al. (2015) have made interpretations of Schumann resonance observations in Antarctica. The purpose of this note is to document published evidence that raises substantial questions about these interpretations in two categories, including (1) the response of the characteristic heights of the Schumann cavity to energetic radiation on the solar cycle time scale and (2) the response of global surface air temperature to the 11-year solar cycle. These categories will be discussed in turn.

Response of the Schumann cavity to ionizing radiation

Observations at Vernadsky, Antarctica show Schumann resonance modal frequency increases in phase with the solar cycle, in agreement with earlier results at other measurement sites by Kulak et al. (2003) and Satori et al. (2005). Nickolaenko et al. (2015) use the same theory for a uniform waveguide used by other investigators to interpret their observations, namely

$$f_n \approx f_n^{(0)} \sqrt{\frac{h_e(f_n)}{h_m(f_n)}} \quad (1)$$

where $f_n^{(0)} \equiv (c/2\pi a)\sqrt{n(n+1)}$,

Where f_n are modal frequencies, h_e and h_m are the lower and upper characteristic heights of the ionosphere, c is the speed of light and a is the radius of the Earth. Nickolaenko et al. (2015) argue that the observed modal frequency increases are to be explained by an increase of h_e near solar maximum due to a decrease in galactic cosmic radiation at solar maximum. In contradiction, many published results on the solar cycle time scale (Kulak et al., 2003; Satori et al., 2005) and on shorter time scales (Roldugin et al., 2003; Roldugin et al., 2004; Dyrda et al., 2015; Zhou and Qiao, 2015; Satori et al., 2015) support a dominant influence for frequency increases from a decrease in the upper characteristic height h_m due to the ionizing effects of solar X-radiation.

The decrease of galactic cosmic rays at solar maximum is well established (Hargreaves, 1992). The problem in the present context is the minor change (tens of percent) in this form of ionizing radiation in comparison with the changes in solar X-radiation (exceeding two orders of magnitude) over the solar cycle (Danilov, 1998; Satori et al., 2005). Furthermore, it is has been shown that large changes in ionizing radiation are needed to enact substantial changes in characteristic heights (Williams and Satori, 2007). Nickolaenko et al. (2015) estimate a 1 km change in the 'knee' height in the model of Mushtak and Williams (2002). A change in the knee height alone would not be expected to have any change in the Schumann resonance frequencies since it lies between the two characteristic heights (Greifinger et al., 2007).

If we make the generous assumption that the increase in h_e is the same as the increase in the knee height above it, then we can use equation (1) to estimate the magnitude of the first mode frequency increase, in the same manner as Satori et al. (2005). Using the same two reference heights (55.1 km and 99.1 km), and assuming a 1 km increase to 56.1 km, we calculate a frequency increase of 0.08 Hz. The measured frequency increase over the 11 year solar cycle in Satori et al. (2005) is 0.20 Hz. This calculation indicates that the suggestion of Nickolaenko et al. (2015) is not adequate to account for the observations. The modification of the lower characteristic height may contribute to the observed increase in modal frequency, but the dominant contribution comes from the change in the upper characteristic height. In contrast, Satori et al. (2005) found earlier that a 5 km decrease in the upper characteristic height was needed to account for the observed 0.20 Hz increase in first mode frequency at solar maximum.

Nickolaenko et al. (2015) object to the idea, prevalent in the publications noted above, that solar X-radiation from the Sun is increasing the ionization in the 90-100 km altitude interval to lower h_m on the basis that "X-rays and gamma rays modify the ionosphere below the 65-70 km altitudes… and provide minor impact around the 100 km altitudes". This argument ignores the major distinction between the photon energy of solar X-radiation (10s of keV) and the photon energy in exceptional gamma ray flares (~MeV, Palmer et al., 2005; Inan et al., 2007), the latter with notably deeper penetration into the Earth's atmosphere (Satori et al., 2015).

In an earlier survey, Nickolaenko and Hayakawa (2002) noted that "we cannot expect a considerable modification of resonance frequencies… by an asymmetric disturbance (like the day-night asymmetry)". This expectation is inconsistent with many published results (Roldugin et al., 2003; Kulak et al., 2003; Roldugin et al., 2004; Satori et al., 2005; Dyrda et al., 2015; Zhou and Qiao, 2015; Satori et al., 2015) involving asymmetric X-radiation on the Schumann cavity from the Sun.

Response of global temperature to the 11-year solar cycle

The observations at Vernadsky also show that the magnetic intensity in the Schumann resonance region is positively correlated with the 11-year solar cycle, with a substantial ~60% decline from solar maximum to solar minimum. As one possible explanation for the increased intensity at solar maximum, Nickolaenko et al. (2015) argue that a decrease in global temperature is responsible, with attendant decrease in the tropical lightning source. Based on an earlier analysis linking tropical temperature and Schumann resonance intensity by Sekiguchi et al. (2006) on an interannual time scale (but not the 11-year time scale), the authors argue for a change of 1.6 ^{0}C in the global tropics, or a change of 0.3 0C in the tropical land temperature on the 11-year time scale. The authors have not examined the actual global temperature variation over that portion of the solar cycle overlapped with the Vernadsky observations they show. The evidence on the global tropical temperature anomaly available at NASA GISS does not support their premise.

The integrated energy output from the Sun is now well measured and the total variation over the 11-year solar cycle is only of the order 0.1%. In contrast, the variations in global temperature on the diurnal, semiannual and annual time scales, and the response of global lightning on the same time scales, are much greater (Williams et al., 1999). Accordingly, there is no reason to expect a large (1.6 ^{0}C) change in global air temperature on the 11-year time scale. This expectation is quantitatively consistent with global analyses (Camp and Tung, 2007; Tung and Camp, 2008; Zhou and Tung, 2013) on the solar cycle time scale, showing at most a 0.1C amplitude variation in surface air temperature over the solar cycle. This result is more than an order of magnitude smaller than the inferences of Nickolaenko et al. (2015). Alternative explanations for the solar cycle modulation of the Schumann resonance intensities at high latitude stations in both southern and northern hemispheres (Williams et al., 2014; Satori et al., 2015), and involving energetic electrons from the radiation belt, deserve further attention.

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