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Common Cycles of Solar Activity and Antarctic Oscillations

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Abstract

The Antarctic Oscillations play important role on various regional and global climatic event. These oscillations are used in study of recent climate change and to improve our knowledge about the climate dynamics. The main sources of these oscillations are the influence of solar activity on climatic variations and global warming. The solar activity affects climatic processes by the Total Solar Irradiance (TSI) variations, solar wind and solar magnetic field. The solar magnetic field and solar wind modulate the variations of heliosphere, geomagnetic field and cosmic rays, whose effect on atmosphere and climate is stronger on high-latitude polar regions. The cycles of solar magnetic field are connected with the North-South (N-S) solar asymmetry of sunspots. The solar influence on Antarctic Oscillations are analyzed by centennial time series of TSI and N-S solar asymmetry. The Antarctic Oscillations are represented by the time series of Southern Annular Mode (SAM) since 1850. The Common cycles of solar activity and Antarctic Oscillations are determined by the Method of Partial Fourier Approximation (PFA). Various common solar and atmosphere cycles in narrow frequency bands are detected, whose periodicity is between 3 and 80 years. This result may help to divide natural solar from anthropogenic effect in recent global warming and to improve scenario of future climate change.

Keywords: solar activity, Southern Annular Mode (SAM), TSI, N-S solar asymmetry, relative humidity.

Introduction

The Antarctic oscillation (AAO) or Southern Annular Mode (SAM) is a weather phenomenon at the Antarctic pole South of 40° latitudes. It is an important mode of climate variability for the Southern Hemisphere. The Antarctic Oscillation refers to a large scale alternation of atmospheric mass between the mid-latitudes and high latitudes surface pressure. It is defined as the difference of zonal mean sea level pressure between 40°S and 65°S. The AAO has the potential for clarifying climate regimes in the southern hemisphere.

The solar activity cycles affect all surface geosystems, including weather and climate indices, winds, rains, snow covers, mean sea level, river streamflows and other hydrological cycles. These processes are due mainly to the Total Solar Irradiance (TSI) variations, followed by weather and climate changes. Recently a new mechanism of climate modulation, based on cosmic ray variations, has been discovered. This mechanism explains chain processes arising from cosmic ray (CR) modulation by the heliosphere and geomagnetic field, followed by ozone production in near tropopause and water content change. The atmospheric water is the most powerful greenhouse gas and its changes produce significant variations of the temperature. The CR modulation by heliosphere depends on solar wind and solar magnetic field variations, represent by North-South (N-S) solar asymmetry. The solar activity affects terrestrial systems by means of direct radiation over Earth surface, influences charged particles of the solar wind, and the solar magnetic field. The solar wind directly affects Earth magnetic field, ionosphere and atmosphere. The variations of solar magnetic field modulate solar wind and cosmic rays in the frame of the solar system. The cosmic rays near Earth are modulated by Earth magnetic field variations, too. Recently, a new mechanism of climate variations, due to cosmic rays was proposed (Kilifarska, 2015; Kilifarska and Bojilova, 2019; Velichkova and Kilifarska, 2020, 2021). According to the new models, the cosmic rays produce an ionization of the atmosphere, changes of atmospheric conductivity, and lightning, and an increase of ozone concentration. This mechanism is based on chain processes near tropopause by ozone production, temperature variations, followed by vertical winds and water content change. The last step of this chain affects strongly surface temperature, because the atmospheric water is one of the most powerful greenhouse gas. This model provides an explanation for the cascade processes in which cosmic rays, whose total energy is relatively small, cause climatic effects with much more energy. The solar activity cycles modulate the cosmic rays directly by the heliosphere and indirectly by the geomagnetic field changes, whose effect is visible mainly at high latitudes and regions with strong geomagnetic anomalies.

Data and Methods

The solar data are presented by the Total Solar Irradiance (TSI) and North-South solar asymmetry variations. The daily reconstruction of TSI data since 1850 is a composite of SATIRE-T reconstruction from (Krivova et al., 2014) for 1850 to 22 August 1974; and SATIRE-S reconstruction from (Yeo et al., 2014) for 23 August 1974 onwards (Fig.1). The 0.1-year values of TSI are calculated by means of robust Danish method (Juhl, 1984; Kegel, 1987; Kubik, 1982). This method allows to detect and isolate outliers and to obtain accurate and reliable solution for the mean values.

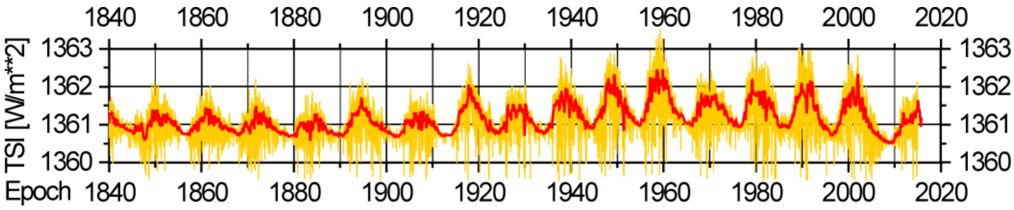

Figure 1. Time series of 0.1-year (in orange color) and daily values (in yellow color) of TSI.

The North-South solar asymmetry (Fig. 2) is determined from the relation $(S_n\text{-}S_s)/(S_n+S_s)$, where the S_n and S_s are monthly sunspot area on the Northern and Southern solar hemispheres, respectively (in units of millionths of a hemisphere). The data since 1874 are observed by the Royal Greenwich Observatory and merged after 1976 with the US Air Force (USAF) and the US National Oceanic and Atmospheric Administration (NOAA) data by D. Hathaway (https://solarscience.msfc.nasa.gov/greenwch.shtml).

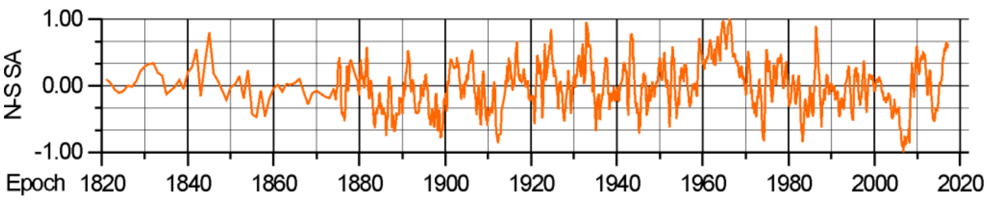

Figure 2. Time series of North-South solar asymmetry.

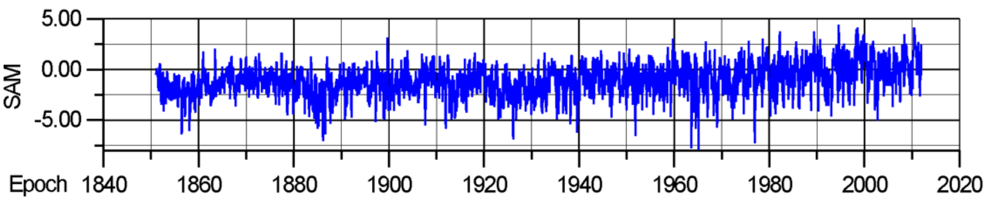

Figure 3. The time series of and Southern Annular Mode (SAM).

The Antarctic Oscillation time series since 1851 are prepared in Physical Science Laboratory of NOAA by the Method, described in (Gong and Wang, 1999) and available online at https://psl.noaa.gov/data/20thC_Rean/timeseries/monthly/SAM/sam.20crv2c.long.data (Fig. 3). The Antarctic Oscillation is defined as the difference of zonal mean sea level pressure between 40°S and 65°S. Additional time series of mean relative humidity and temperature from the belts 40°S - 65°S and 65°S - 75°S are shown in Fig.4.

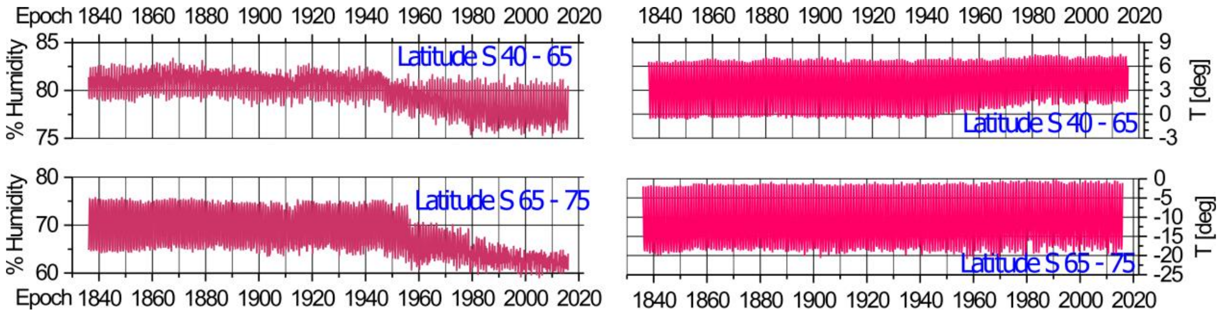

Figure 4. Relative humidity and temperature T from the belts 40°S - 65°S and 65°S - 75°S.

Results

The common cycles of SAM and solar activity are presented in Figs. 5 and 6.

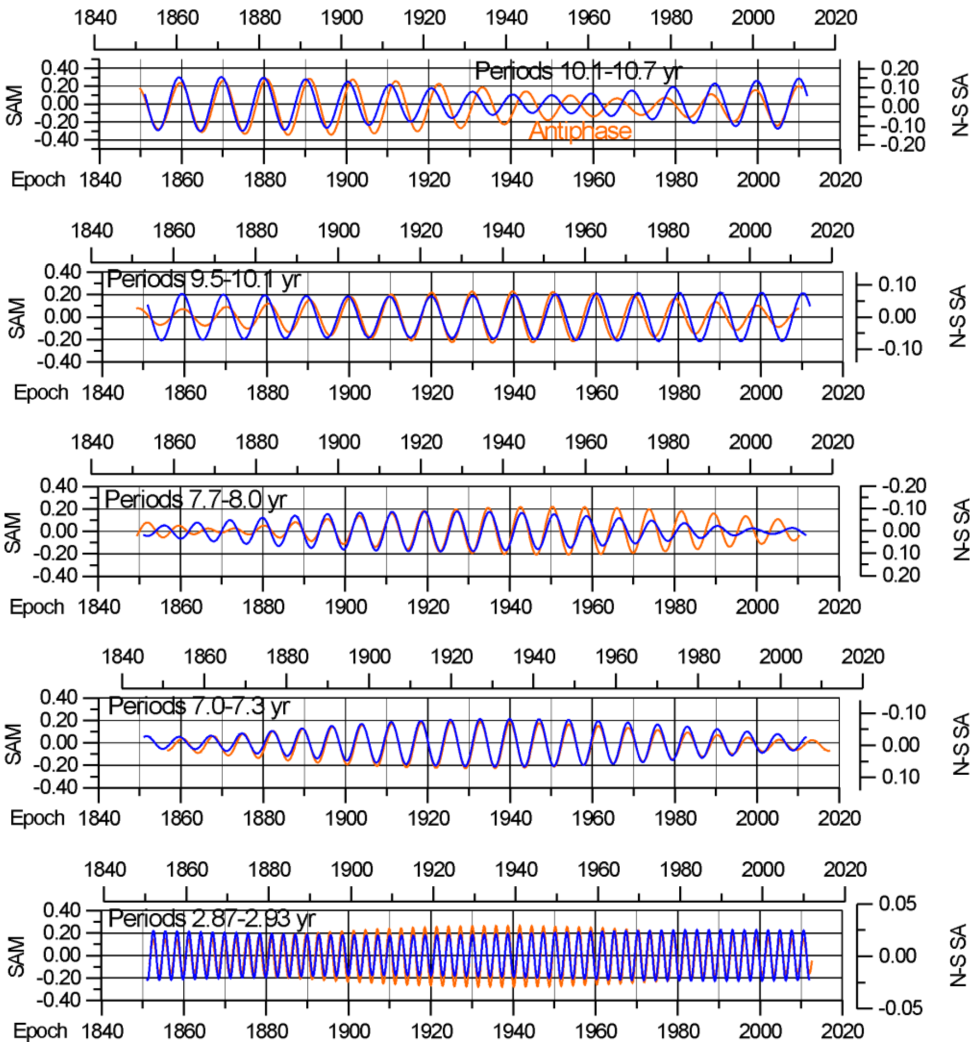

Figure 5. N-S solar asymmetry(orange color) influence on Antarctic Oscillation (blue color) with decadal and subdecadal periodicities

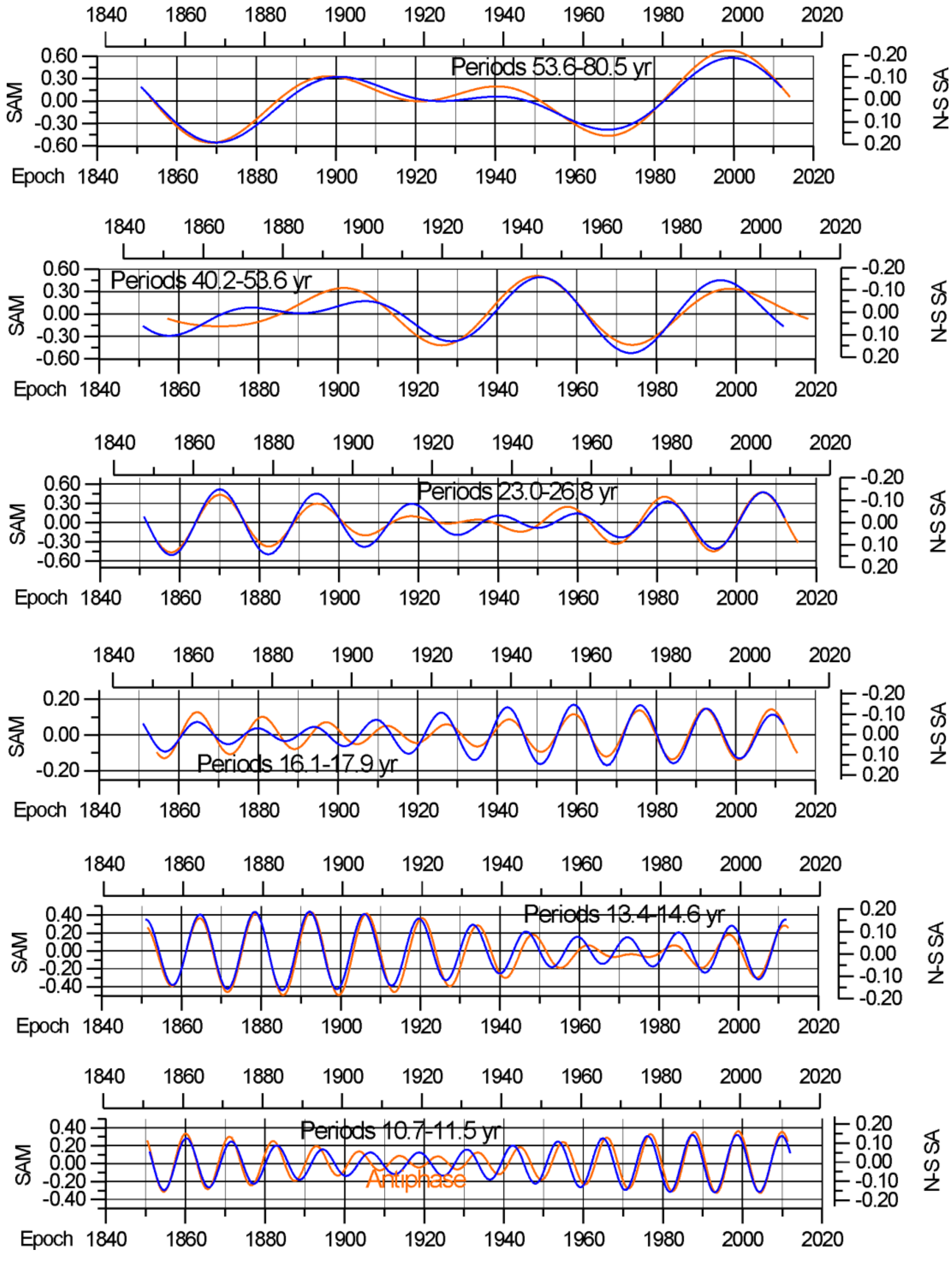

Figure 6. N-S solar asymmetry (orange color) influence on Antarctic Oscillation (blue color) with decadal periodicities.

The N-S solar asymmetry modulates solar magnetic field and corresponding variations of solar wind and heliosphere. These variations affect geomagnetic field, too. The high energy cosmic rays and charged particles penetrate heliosphere and they reach the Earth atmosphere after modulation by geomagnetic field. Maximal interaction between cosmic rays and atmosphere occur in high-latitude polar area, so the oscillations of the high latitude parts of the atmosphere are expected to be induced by cosmic rays, modulated by solar magnetic field variations. It is possible to detect tis interaction by common analyze of N-S solar asymmetry Index and Polar Indices. Common cycles of N-S solar asymmetry Index and Southern Annular

Mode are detected by the PFA Method (Chapanov et al., 2017) in 5 subdecadal (Fig. 5) and 6 decadal (Fig. 6) narrow frequency bands, whose periods are between 3 and 80 years. The determined common solar and atmospheric cycles have good agreement with short 30-year phase reverses around the 11-year solar cycle.

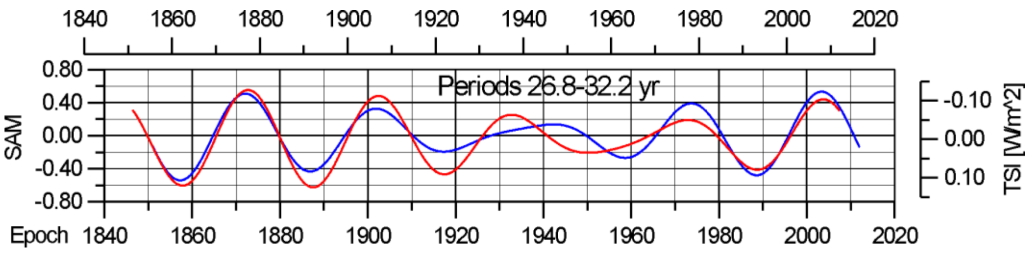

Figure 7. TSI (orange color) influence on Antarctic Oscillation (blue color) with decadal periodicities.

The decadal and subdecadal influence of N-S solar asymmetry on Antarctic oscillations is presented by common solar-ozone cycles are divided into 9 narrow frequency bands, whose periods are: 53.6-80.5 yr; 40.2-53.6 yr; 23.0-26.8 yr; 16.1-17.9 yr; 13.4-14.6 yr; 10.7-11.5 yr; 10.1-10.7 yr; 9.5-10.1 yr; 7.7- 8.0 yr; 7.0- 7.3 yr; and 2.87-2.93 yr

The mean variations of Antarctic Oscillation are determined in 2-year sliding window (Fig.8), where significant positive trends are visible after 1920 and 1965. The time series of relative humidity and temperature from latitudinal belt 40S – 65S demonstrate unusual behavior of strong jumps in 1945 and significant linear trends after 1945 and 1975/1980, more visible in the case of relative humidity. Possible explanation of these abrupt changes are jumps in solar magnetic field, expressed by the time series of N-S solar asymmetry (Fig. 9).

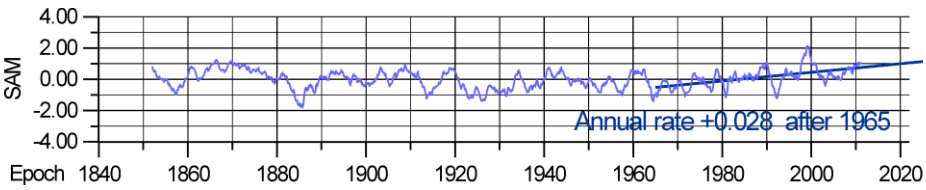

Figure 8. Mean variations of Antarctic Oscillation, determined in 2-year sliding window.

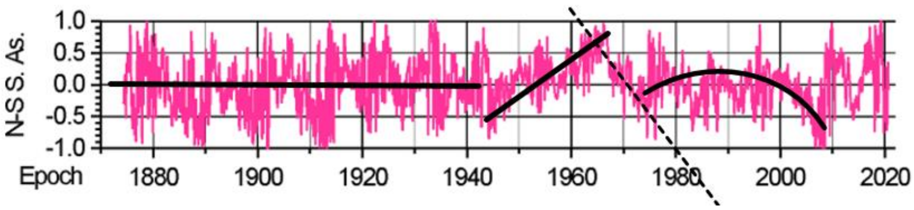

Figure 9. Some linear trends in variations of N-S solar asymmetry and strong jumps in 1945, 1975 and 2008.

Conclusions

The solar activity influence on Antarctic Oscillations is conducted by TSI variations and N-S solar asymmetry. Various narrow frequency bands are detected with common cycles of solar and atmospheric Indices, whose periods are between 3 and 80 years. The influence of N-S solar asymmetry dominates, because over the polar region the cosmic rays are concentrated by focus of geomagnetic field. Another zone of cosmic rays concentration is equatorial part of Pacific ocean, where the cosmic rays produce ozone in lower stratosphere and next strong influence on

ENSO event (Chapanov, 2019, 2021). An important aspect of recent climate change is visible global warming during the past decades. The mean variations of Antarctic Oscillations are calculated in 2-year sliding window. The averaged data have significant rising trends, with annual rate +0.028 after 1920 and 1965. A part of these trends are connected with the anthropogenic effects of global warming, but other significant part should be attached to the jumps of solar magnetic field, geomagnetic field, cosmic rays and stratospheric ozone. Other possible effects on rising trends are influences of solar activity, whose long-term oscillation is in the range of Gleissberg cycles of the solar activity with periodicity 80-120 years. So, in the case of significant long-term solar influence on global warming, connected with the Gleissberg cycles, it is possible to expect some decrease of the linear trends in climatic Indices in nearest future with probable initial epoch after 2030.

The separation of anthropogenic from natural effects of the global warming will be possible by new models of climate oscillations, based on the cycles of solar activity, lunar tides and solar magnetic jumps. Such kind of models of climate change may improve forecast accuracy and climatic scenario.

Acknowledgments

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