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Long-term variations of the surface pressure in the North Atlantic and possible association with solar activity and galactic cosmic rays

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Abstract

Long-term variations of the surface pressure in the North Atlantic for the period 1874–1995 (Mean Sea Level Pressure archive, Climatic Research Unit, UK) were compared with indices of solar and geomagnetic activity and the galactic cosmic ray (GCR) variations characterized by the concentration of the cosmogenic isotope ^{10}Be. A periodicity of ~80 yrs close to the Gleissberg cycle in the intensity of the 11-yr solar cycles was found in the pressure variations at middle latitudes (45–65°N) in the cold half of the year, which is the period of intensive cyclogenesis. It was shown that a long-term increase of pressure in this region coincided with a secular rise of solar/geomagnetic activity which was accompanied by a decrease in GCR intensity. Long-term decreases of pressure were observed during the periods of low (or decreasing) intensities of sunspot cycles. Similar features were also found in the spectral characteristics of geomagnetic activity indices, GCR intensity and pressure at middle latitudes on the quasi-decadal time scale. Effects of solar activity/GCR variations on the surface pressure seem to be more pronounced in the North Atlantic zone of intensive cyclogenesis (near the eastern coasts of North America). The results obtained suggest possible links between long-term variations in cyclonic activity at extratropical latitudes of the North Atlantic and solar activity/GCR variations on the time scales from ~10 to ~100 yrs.

Keywords: North Atlantic; Atmospheric pressure; Solar activity; Galactic cosmic rays; Climate variability

1. Introduction

Solar activity influences on the climate changes are widely discussed nowadays, the variations of galactic cosmic rays (GCR) being considered as an important factor of these influences. There are some evidences of long-term effects of solar activity on cyclonic processes at middle latitudes of the North Atlantic which is an area of the intensive extratropical cyclogenesis. Labitzke and van Loon (1988) showed that the number of cyclones in the western part of the North Atlantic decreases in solar maxima (minima of GCR) in the years with the western phase of quasibiennial oscillations (QBO) of the atmosphere. Tinsley (1988) revealed a clear relationship of solar variability to the average latitude of storm tracks in the North Atlantic also in the western phase of QBO. In this work, we study long-term variations of the surface pressure in the North Atlantic for the period 1874–1995 which allows us to estimate the intensity of cyclonic processes, as well as possible relationships of these variations to solar/geomagnetic activity and GCR intensity.

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2. Analysis of experimental data and discussion

2.1. Time series of the surface pressure in the North Atlantic

As an experimental base of this study, we used the mean monthly data of sea-level pressure in the regular grid $5° \times 10°$ in the northern hemisphere from MSLP archive (ftp://ftp.cru.uea.ac.uk). The data were averaged over different regions of the North Atlantic and over cold (October–March) and warm (April–September) months. We considered the region of middle and subpolar latitudes (45–65°N, 60–10°W) which is an area of the intensive formation and development of extratropical cyclones and the region of lower latitudes (20–40°N, 80–10°W) including a subtropical belt of high pressure.

Time variations of the mean values of sea-level pressure in different regions of the North Atlantic are presented in Fig. 1 for cold and warm periods. The data in Fig. 1 show that there are both short-term (~several years) and long-term variations of the surface pressure in the North Atlantic. Indeed, in the cold half of the year, which is the period of most intensive extratropical cyclogenesis, the 20-yr running averages of pressure at latitudes 45–65°N reveal maxima near 1880–1890 in the 19th century and near the 1960s in the 20th century. This seems to indicate a periodicity of ~80 yrs in pressure variations. At lower latitudes 20–40°N we can also see the 80-yr periodicity, with pressure variations being opposite to those observed at higher latitudes. In the warm period, when the cyclonic activity at middle latitudes is less intensive than in the cold one, no similar long-term variation is observed.

Thus, the data above show a long-term (on the century time scale) periodicity of the surface pressure at middle and subpolar latitudes of the North Atlantic in the period of most intensive cyclone formation that provides evidence of secular changes of the intensity of cyclonic activity in this area. Long-term pressure variations at lower latitudes including a belt of subtropical anticyclones at ~30°N seem to be closely related to those observed in the mid-latitudinal area. Indeed, negative anomalies of pressure at higher latitudes are accompanied by positive anomalies of pressure at subtropical latitudes and vice versa resulting in the well known links between the intensity of Icelandic low and Azores high (Pogosian, 1972; Hurrel, 1995).

Let us compare the long-term changes of sea-level pressure in the region of extratropical cyclogenesis with different indices related to solar activity. In Fig. 2 the 20-yr running averages of the pressure at latitudes 45–65°N in the cold period are presented, as well as sunspot numbers, geomagnetic *aa*-indices and the concentration of ^{10}Be in ice cores from Greenland (Beer et al., 1990) used as a proxy of galactic cosmic ray fluxes. The *aa*-indices characterize geomagnetic activity which depends on the interplanetary magnetic field disturbances modulating GCR fluxes. The cosmogenic isotope ^{10}Be is produced by cosmic ray interaction with nuclei in the Earth's atmosphere and its concentration depends on solar activity and on the strength of geomagnetic field. The ^{10}Be quickly precipitates (during about one year)

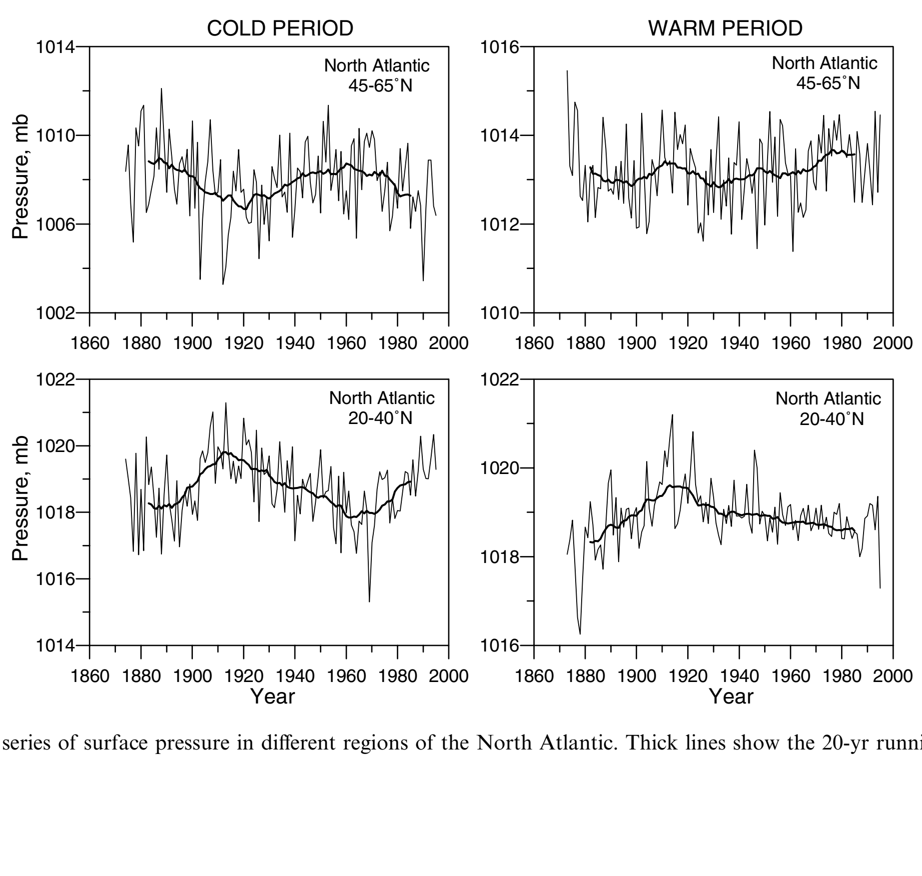

Fig. 1. Time series of surface pressure in different regions of the North Atlantic. Thick lines show the 20-yr running averages.