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Seasonal and inter-annual variations of Schumann resonance signals as observed from the Antarctic and the Arctic

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This paper analyzes two long-term datasets of Schuman resonance (SR) signals recorded in Southern and Northern hemispheres using identical induction-coil magnetometers operated within frequency range from 0.001 to 80 Hz and collected data in the absolute units. The longest 18 years' dataset was recorded at the Ukrainian Antarctic station "Akademik Vernadsky" (65.25° S, 64.25° W) from March 2002 to March 2020. Last six and half year were accompanied by similar observations carried out at "SOUSY" observatory (Svalbard, Arctic, 78.15° N and 16.05° E) started in October 2013. Monitoring of the orthogonal horizontal magnetic field components gave advantages of detailed studying of seasonal and inter-annual variations of SR signal parameters observed at the sub-polar sites in the both hemispheres. This paper discusses the behavior of intensities and peak frequencies of the first SR mode derived from the power spectra of horizontal magnetic field components and averaged over each month of observations. We estimated the level of background ELF radio noise by computing the signal intensity in the minimum between the first and second resonance modes. The time interval since October 2013 when observations were performed simultaneously in the both hemispheres was used to determine the seasonal variations of SR signal and the world thunderstorm activity. The observed seasonal variations of peak frequency values $F = (F_{sn}+F_{we})/2$ occur in 'anti-phase' in different hemispheres. This behavior corresponds to the well-known drift of global thunderstorms along the North-South direction within the subtropical area following the Sun. During the summer (hereinafter we mention the seasons in the Northern hemisphere) the thunderstorms move to the ultimate northern position causing the minimum peak frequency observed in the Arctic and the maximum in the Antarctic. The opposite behavior is observed during the boreal winter. These anti-phase variations repeat from year to year showing an outstanding similarity and might be interpreted as 'electromagnetic seasons'. We found that duration of 'electromagnetic seasons' derived relative the yearly average variations are different for observations performed in the Arctic (winter ~ 4, spring ~ 3, summer ~ 2, fall ~ 3 months) and in the Antarctic (winter ~ 3, spring ~ 2, summer ~ 4, fall ~ 3 months). This discrepancy might be explained by asymmetric position of observatories relative global thunderstorm centers leading to different annual changes of source – observer distances. This effect requires additional investigation although. Variations of the first SR mode intensity $I = (I_{sn}+I_{we})/2$ recorded synchronously in the both hemispheres might be linked to the annual trends in the global thunderstorm activity. The estimates deduced from the SR agree with the published estimates of annual change in the rate of lightning stroke based on the optical spaceborne data. The SR intensity shows an impact of analemma arising from a small eccentricity of the Earth orbit. It manifests itself as an October decrease in the SR intensity present in the records of both hemispheres. This reduction corresponds to decline in the global thunderstorms activity during the start of the fall monsoon period. A singular spectral analysis (SSA) was applied to single out the principal components in temporal variations of SR peak frequency and intensity. The annual variations of peak frequencies are in-phase at the both hemispheres. The semi-annual components are shifted in phase by approximately three months thus causing different duration of 'electromagnetic seasons' mentioned above. Annual intensity variations are shifted for about a quarter of the year. High-frequency variations of intensities show a more complicated shape than the semi-annual pattern, and this requires additional investigation. The inter-annual variations of both peak frequency and intensity demonstrate in-phase behavior in the both hemispheres during the whole 11-year solar cycle. The magnitude of peak frequency inter-annual variations is comparable in the both hemispheres while that in the intensity observed in the Antarctic seems to be bigger. The ELF background demonstrates in-phase seasonal variations while noticeable inter-annual changes are absent. We found that global thunderstorms are independent of the solar cycle phase. The observed inter-annual variations originate from changes in the lower ionosphere driven by the 11-year cycle in the solar activity. We discuss mechanisms that might be responsible for such changes: variations within solar cycle, in particular the X-ray and the UV radiation intensity; alterations in the flux of galactic cosmic rays; precipitation of energetic particles from the magnetosphere.