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Low Solar Activity and the Ionosphere

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Global solar activity of the Sun has been weakening recently. A radio butterfly diagram, synthesized from twenty years of daily full disk images of the Sun at 17 GHz observed by Nobeyama Radioheliograph, shows that both polar and low-mid latitude activities have been declining during the last 20 years. After the deep activity minimum between the cycles 23 and 24, solar activity started to increase in 2009 rather slowly. The year 2013 is expected to be the maximum of the 24th cycle. However, activity is extremely low, lowest in 100 years, and SCOSTEP is organizing one year MiniMax24 campaign observations of solar and terrestrial parameters. In this paper, we study how such a low solar activity influences the terrestrial upper atmosphere by comparing activity indexes of solar and terrestrial upper atmospheres.

For solar activity indexes, we used monthly averaged total radio flux values (1000, 2000, 3750, and 9400 MHz) measured at the Research Institute of Atmospherics (Nagoya University) and the Nobeyama Solar Radio Observatory (National Astronomical Observatory) and monthly mean values of relative sunspot numbers provided by Solar Influences Data Analysis Center (Royal Observatory of Belgium). It is known that radio flux values around 10 cm (3000 MHz) show good correlation with relative sunspot numbers. As radio measurements are not sensitive to weather (cloud, rain, or other) and ionosphere conditions, flux values are often used as a quasi realtime solar activity index. Due to a robust calibration method of radio flux measurements, long-term uniform values are available. Radio flux values at 2800 MHz (F10.7) from Canada have been used as standard solar activity index since 1947. Also in Japan, measurements at 3750 MHz (8 cm) have been continuing more than 61 years since Nov. 1951 and also other long observation at 1000, 2000, and 9400 MHz are available. However, it has been noticed that radio flux values after the year around 2000 are systematically higher than inferred from sunspot numbers, or sunspot numbers are systematically smaller.

For activity index of terrestrial upper atmosphere, we used monthly median values of ionospheric characteristic frequency 'foF2' measured at Kokubunji station (National Institute of Information and Communications Technology) at local noon. The frequencies foF2 have two peaks in a year. To avoid seasonal variations, 13 months running average values (weighted 0.5 at both ends) are used. This frequency corresponds to the plasma frequency of the highest electron density layer (F2 layer) in the ionosphere. Radio waves higher than foF2 can get through the ionosphere, and that lower than foF2 are reflected. Hence this frequency is the characteristic frequency of the ionosphere. Electron density in the ionosphere is determined by balance between photo ionization by solar EUV radiation and recombination. Hence, foF2 and electron density must be closely related to solar activity. We study how recent low solar activity is influencing these quantities. Analyzed period is 43 years since 1969 January up to 2011 December and the total data number is 516.

Analysis methods are: 1) compare time series plots of each index, 2) create correlation plots between solar and ionospheric data, and 3) calculate correlation coefficients between them. Results are: Correlation between radio flux at 2000 GHz and electron density has the highest coefficient of 0.993. Superposition of scaled 2000 MHz flux and electron density time series show that electron density during 23/24 minimum and also during 24th cycle are systematically lower than inferred from 2000 MHz flux. Radio flux correlates better with ionospheric electron density than sunspot numbers.

Keywords: solar activity, long-term variation, sunspot number, total radio flux, ionosphere, foF2