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The Effect of Forbush Decreases on Atmospheric Aerosols and Clouds from The PATMOS-x Satellite from 1978 to 2018

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The solar system is constantly changing, and it is important for us to understand how our climate and weather changes in response to the solar activity during both long-time scales (e.g. the 11-year solar cycle) and short time scales (e.g. days to weeks during For-bush Decreases (FDs)). Solar variability causes a corresponding modulation of the incident number of cosmic rays in Earth's atmosphere. Previous work by [Veretenenko and Pudovkin, 1997], [Svensmark and Friis-Christensen, 1997], [Palle Bago and Butler, 2000], [Svensmark et al., 2016], [Harrison and Ambaum, 2010], and other researchers have discussed this cause-effect relationship from an experimental and theoretical approach. Since the 1970s, global observations of the Earth's system by satellites are offering an invaluable source of information about cloud parameters.

In this study, we used the newly calibrated PATMOS-x (Pathfinder Atmospheres Extended) data set during the period from 1978 to the present. A method for capturing the connection between cosmic rays and meteorological measurements has been conducted by superposition analysis of FD events for time series (36 days) and the Monte Carlo bootstrap test to evaluate significance level of the integrated signal for 9 days after the minimum in FD. We have reviewed results, primarily about cloud emissivity (Achieved Significance Level (ASL >99%), surface brightness temperature (ASL >99%), and cloud fraction (ASL >99%). Some of the results support the proposed relationship between solar activity and temperature. This result indicates that the amount of incident cosmic rays decreases due to FDs, global average temperature increases [Friis-Christensen and Lassen, 1991], [Harrison and Ambaum, 2010]. In addition, PATMOS-x parameters of cloud probability, cloud mask, and cloud fraction, which all means cloud coverage on the Earth shows statistically significant signals following FDs. In some previous research, IR-detected cloud fraction from International Satellite Cloud Climate Project (ISCCP) and combined liquid and ice cloud fraction, effective emissivity from the Moderate Resolution Imaging Spectroradiometer (MODIS) also show connection with FDs, see [Svensmark et al., 2009], [Svensmark et al., 2016], [Marsh and Svensmark, 2000a], Todd and Kniveton [2004]. The relationship between the observed changes in cloud amount and the resulting solar forcing is discussed. On the other hand, “Cloud water content" from Special Sensor Microwave Imager (SSM/I), “Liquid water path", and “Optical thickness" from MODIS also showed as significant signals by FDs, see [Svensmark et al., 2009], [Svensmark et al., 2016], however a similar parameter about “optical thickness" and “integrated total cloud water over whole column g/m2" from PATMOS-x dataset does not have high significant signals by a bootstrap test with ASL of 77.03 and 92.51% respectively. Moreover, significant results

are reported for several new cloud parameters from the PATMOS-x dataset (e.g. cloud type, brightness temperature, measurements by different wavelength 0.65, 0.86, 3.75, 11.0, and 12.0 μm and others) and Fu-Liou model is used for estimation of changed radiations in the atmosphere. An interaction between CCN and radiation has not been investigated well yet. It is necessary to still more to learn about these results for further understanding of Earth's atmosphere.