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Effects of Forbush Decreases on Clouds as determined from PATMOS-x

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This study examines the relationship between cosmic rays and clouds during Forbush decreases (FDs) to understand the cause-effect relationships between cloud microphysics, cloud condensation nuclei (CCN), and ionisation in the atmosphere. The results of a Monte Carlo analysis of cloud parameters during FDs from newly calibrated satellite data, namely, the Pathfinder Atmospheres Extended (PATMOS-x) from 1978 to 2018, show the connections between some cloud parameters and FDs. For context, FD is the event where, the amount of cosmic rays arriving in the atmosphere decreases and recovers over several days. Other studies have shown that FDs impacted the cloud fraction, aerosol optical depth, CCN, water content, and cloud effective radius (r_{eff}) in the atmosphere. Using the Monte Carlo analysis, nine atmospheric parameters from the dataset were evaluated for a significant response level to FDs. Each FD event added (after the first event) reduces the noise, but only the strongest events add a significant signal (exceptionally when the 2nd and 5th rank FD data are added, the signal/noise ration dropped due to change of satellite version). We found that cloud fraction shows statistically significant signals following FDs at an achieved significance level of 0.33%. Cloud emissivity also showed highly significant signals from the analysis, however these cannot be determined as physical cause by FDs since the response starts a week before the FDs. In contrast, the cloud optical depth, integrated total cloud water over the entire column, and r_{eff} did not show any significant signals in frameworks of the applied methods. The top-of-atmosphere brightness temperature at nominal wavelengths of 3.75, 11.0, and 12.0 µm and surface brightness temperature were analysed anew and showed significant signals. The estimated brightness temperature changes from a radiative transfer model (Fu-Liou model) show consistent results with the observed changes in cloud parameters during FD events. Among analysed several atmospheric/cloud/aerosol parameters, cloud fraction and the top-of-atmosphere brightness temperature at nominal wavelengths of 3.75, 11.0, 12.0 µm remain the only parameters depicting a statistically significant and correct-phase response to FDs.