Does a cosmic ray—cloud link operate at local spatial scales?

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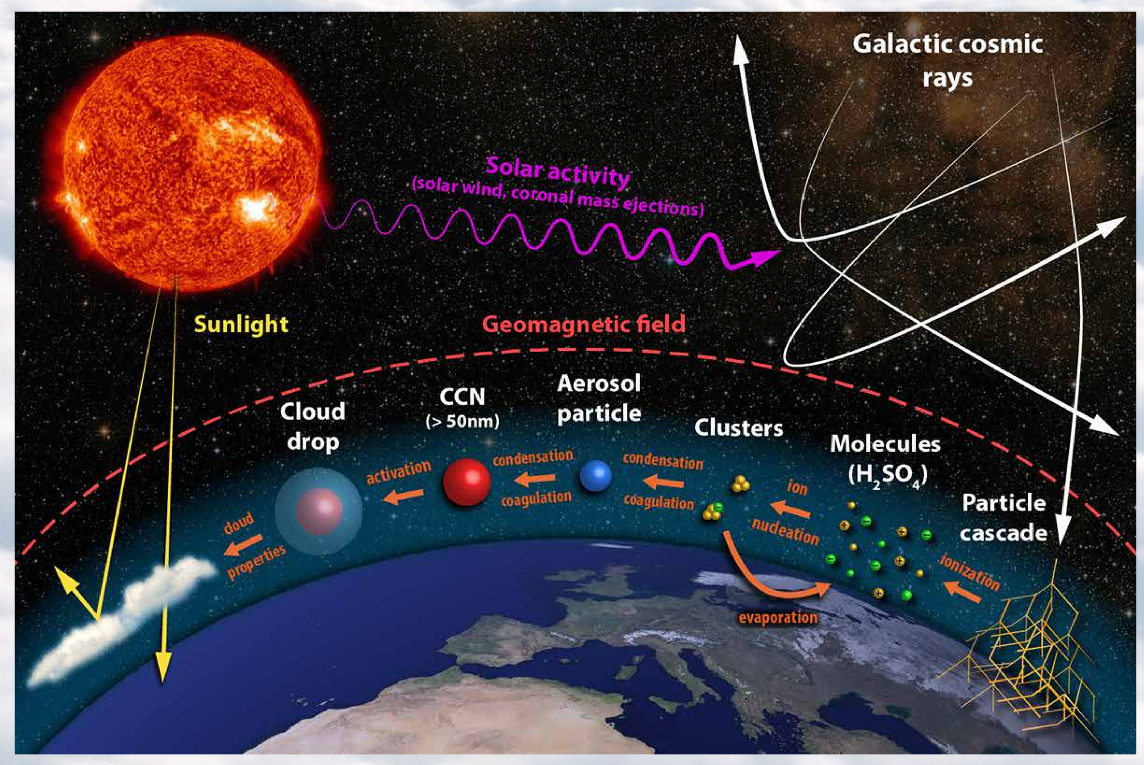
Introduction

A hypothesized link between the solar-modulated cosmic ray (CR) flux and Earth's cloud cover is still a debated topic in solar-terrestrial physics. Recently, experimental and modeling studies suggest that the influence of ion-mediated nucleation on clouds globally is very small or negligible (Pierce and Adams, 2009; Almeida et al., 2013). Additionally, it was shown that incorrect methods of assessing the statistical significance of observational results may have produced false positive results and erroneous conclusions in some past studies (e.g. Laut, 2003; Laken et al., 2012). However, open questions remain with regards to whether or not cloud properties are influenced by CR under specific atmospheric conditions (i.e. second-order) over limited areas, where small variations in cloud condensation nuclei (CCN) may have a large impact on clouds. For example, marine stratocumulus clouds in areas of low aerosol concentrations may be sensitive to small changes in CCN (e.g. ship tracks). Furthermore, cosmic ray flux also modulates the global electric circuit (GEC) flowing vertically from the ionosphere to the Earth's surface. Thunderstorms and electrically active clouds generate continuously current maintained by atmospheric conductivity that is influenced by cosmic ray induced atmospheric ionization. Thus changes in GEC, beside the implications for cloud microphysical properties, influence also the lightning activity over the globe.

Using daily timescale epoch-superpositional (composite) analysis during Forbush decrease events (short-term reductions in the CR flux), and robust Monte Carlo significance testing, cloud cover and properties are analyzed over oceans where such conditions occur with the aim of testing for an observable CR—cloud response.

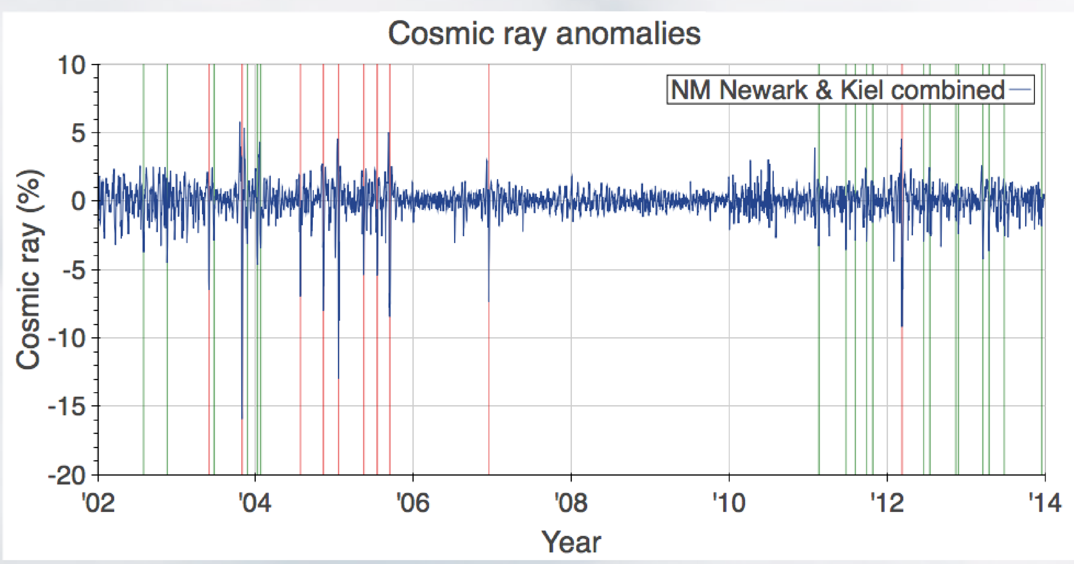
Ion-mediated nucleation (clean-air mechanism)

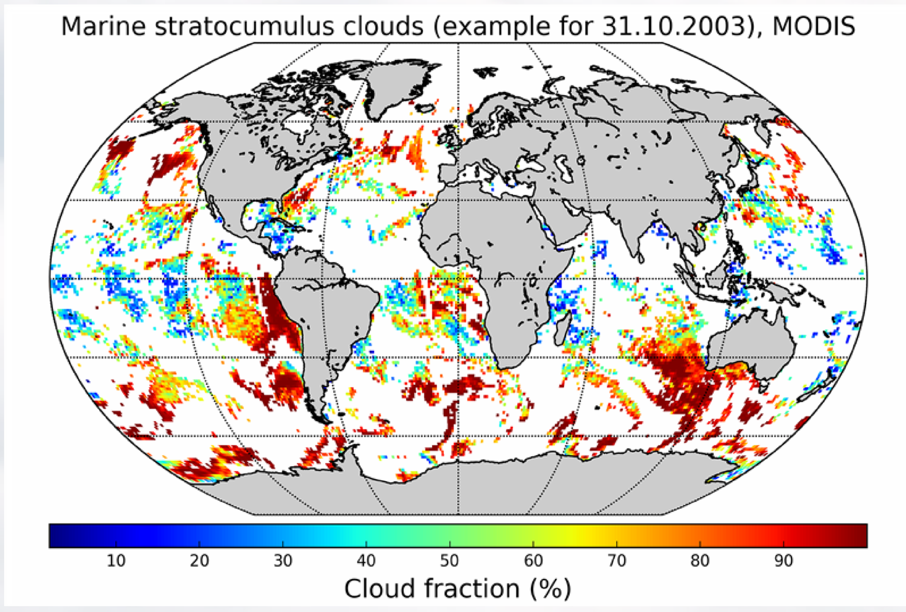


Data & Methods

Cloud cover and cloud properties are taken from MODIS (Moderate Resolution Imaging Spectroradiometer) instrument onboard of Aqua satellite. Daily data (MYD08_D3_v6, http://giovanni.sci.gsfc.nasa.gov) on a 1° × 1° grid from 05/07/2002 – 31/01/2016 were used for seven different cloud parameters: **Cloud fraction, Cloud Top Pressure, Combined Cloud Optical Thickness, Ice Cloud Optical Thickness, Liquid Water Cloud Optical Thickness, Ice Cloud Effective Particle Radius and Liquid Water Cloud Effective Particle Radius**.

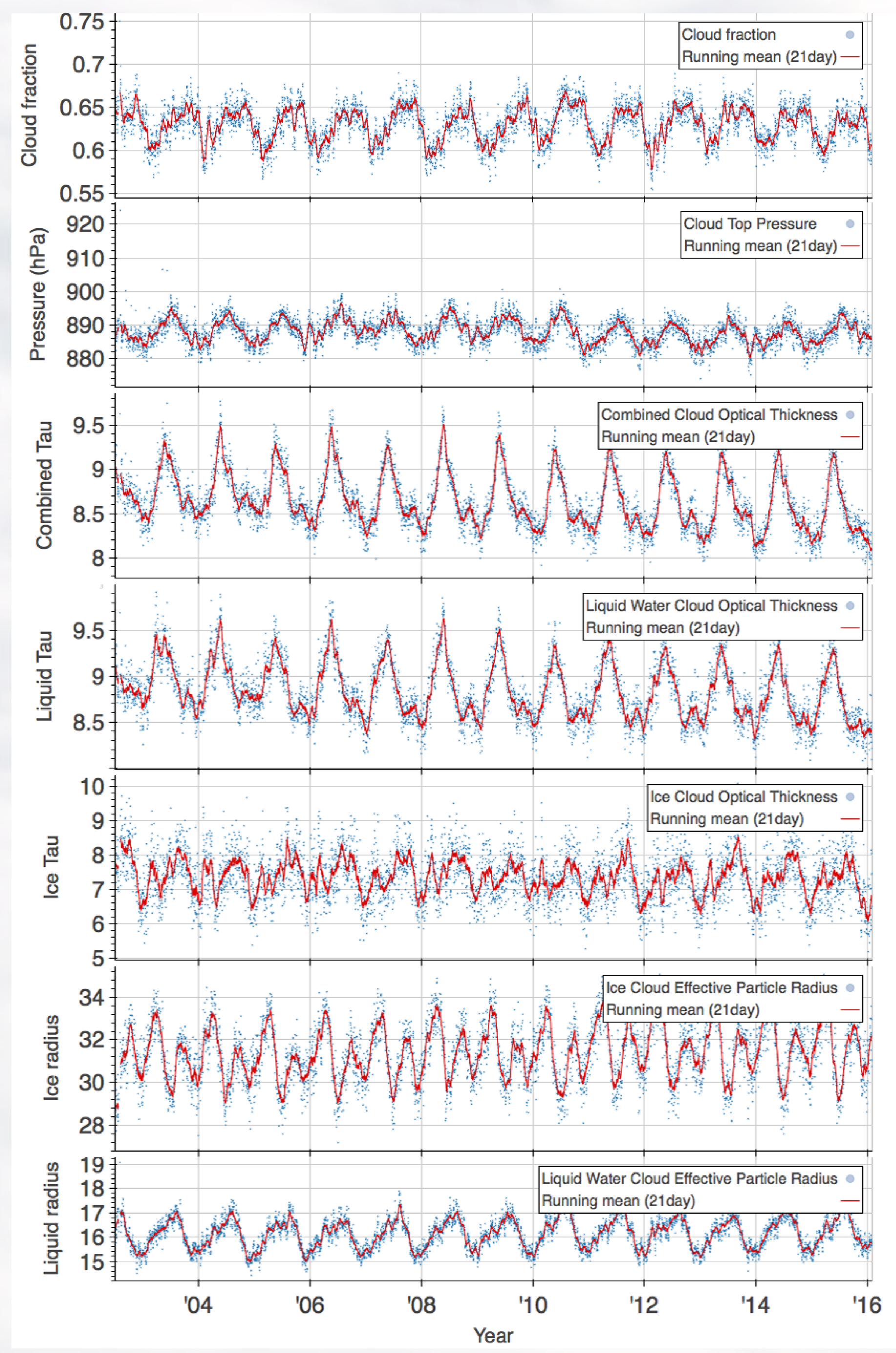
Cosmic ray flux data are combined (mean) from Newark (39.7N, 75.7W, Rc=2.40 GeV) and Kiel (54.3N, 10.1E, Rc=2.36 GeV) neutron monitors during the period from January 2002 to December 2014. Altogether the 29 strongest Forbush decrease (FD) events dates are obtained from FD lists in Kristjansson et al., 2008 and Lingri et al., 2016 (marked as green and red vertical lines on the figure with CR anomalies; red lines denote events with larger CR decrease than 5%).



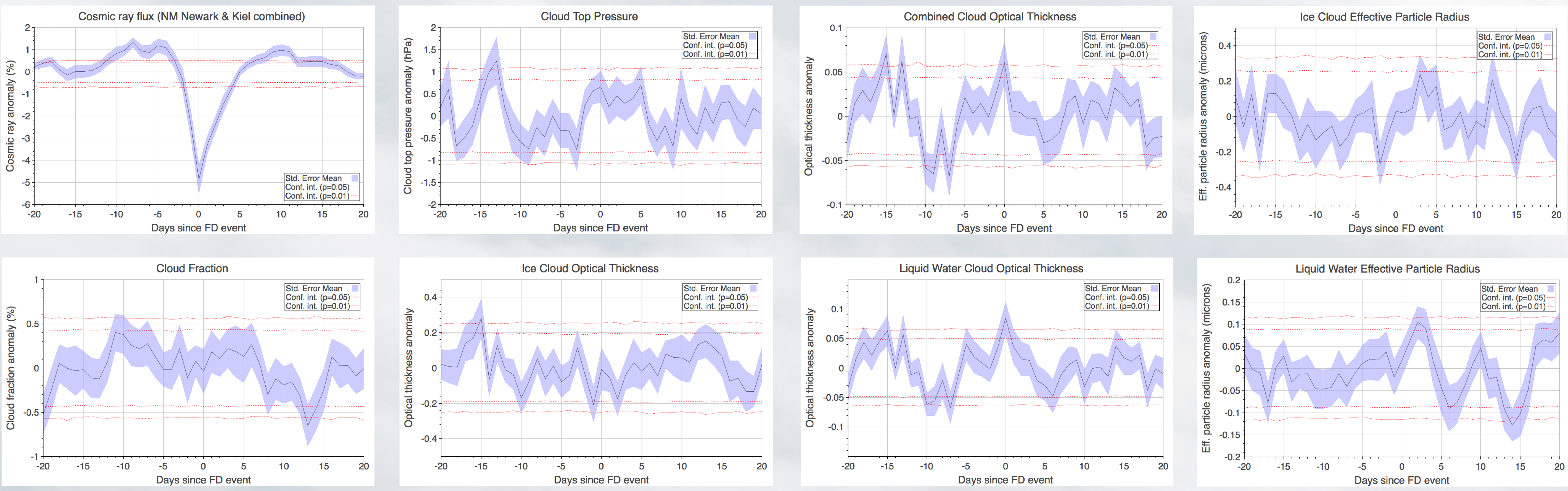


To isolate marine stratocumulus clouds only, grid cells matching the following criteria were selected from the global cloud gridded data: cloud has to be over the ocean, with cloud top pressure larger than **800 hPa** (boundary layer), and with the optical thickness of **3.6–23** (e.g. see example plot for 31/10/2003). The selected grid cells were then averaged over the globe using area-weighting.

Anomalies for each analyzed parameter and time step were calculated by subtracting the running mean of 21-days from the original averaged data, allowing us to construct composites according to the Forbush decreases event list. To calculate significance intervals for the analyzed parameters 10,000 Monte Carlo (MC) simulations were performed. All methods about filtering the data, building composites and MC significance testing are in detail described in Laken and Čalogović, 2013.



Results



Conclusions

We find **no statistically significant response** in marine stratocumulus clouds for any of seven analyzed cloud parameters to changes in cosmic rays flux during the short-term reductions in cosmic ray flux (Forbush decrease events) in the period from 2002 to 2014.

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