Space-borne evidence of regional and seasonal Arctic cooling by brighter and wetter clouds

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Arctic Amplification describes the recent period in which temperatures are rising twice as fast as the global average and sea ice and the Greenland ice shelf are approaching a tipping point. As a result, the Arctic's ability to reflect solar energy decreases and absorption by the surface increases. A simple assumption would be that if the sea ice extent has been reduced, then the spectral reflectance at the top of the atmosphere - R_{toa} - would have also decreased across the Arctic. On the other hand, Arctic reflectivity also largely depends on the presence of clouds, shielding the underlying surface, and on changes of their optical and physical properties. Thus, the assessment of trends of spectral reflectivity and cloud properties are essential to understand the drivers of Arctic Amplification as well as the interactions between the components of the Arctic cryosphere. We observationally tackle the stated problem investigating changes of R_{toa} at selected wavelengths making use of spaceborne measurements of the Global Ozone Monitoring Experiment (GOME onboard ERS-2 and MetOp A/B) and of the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY onboard Envisat) for the period 1995-2018. We complement this record with cloud properties and fluxes, inferred from measurements of the post-meridiem orbits of the Advanced Very High Resolution Radiometer (AVHRR onboard POES) and validated against coincident measurements collected at in-situ Arctic stations. Although the pan-Arctic reflectivity has only slightly decreased, the analysis of regional trends shows distinct areas where the reflectivity trends diverge. While darkening areas can be attributed to seasonal sea ice decline, an increase of Arctic brightness over sea ice free regions can be largely attributed to changes in the optical properties of clouds. Clouds increase the pan-Arctic reflectance by decreasing their ice and increasing their supercooled liquid water contents at polar temperatures. In the last twenty years, clouds have cooled the surface at low Arctic latitudes both in summer and spring while contributing to its warming over the circumpolar belt in spring. Comparison with trends calculated by models for the same time span show a general agreement in average quantities of clouds and fluxes, while spatial variability is not well captured.