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Glacier albedo decrease in the European Alps: potential causes and links with mass balances

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Both mountain glaciers and polar ice sheets are losing mass all over the Earth. They are highly sensitive to climate variation, and the widespread reduction of glaciers has been ascribed to the atmospheric temperature increase. Beside this driver, also ice albedo plays a fundamental role in defining mass balance of glaciers. In fact, dark ice absorbs more energy causing faster glacier melting, and this can drive to more negative balances.
Previous studies showed that the albedo of Himalayan glaciers and the Greenland Ice Sheet is decreasing with important rates. In this contribution, we tested the hypothesis that also glaciers in the European Alps are getting darker. We analyzed 16-year time series of MODIS (MODerate resolution Imaging Spectrometer) snow albedo from Terra (MOD13A1, 2000-2015) and Aqua (MYD13A1, 2002-2015) satellites. These data feature a spatial resolution of 500m and a daily temporal resolution. We evaluated the existence of a negative linear and nonlinear trend of the summer albedo values both at pixel and at glacier level.
We also calculated the correlation between MODIS summer albedo and glacier mass balances (from the World Glaciological Monitoring Service, WGMS database), for all the glaciers with available mass balance during the considered period. In order to estimate the percentage of the summer albedo that can be explained by atmospheric temperature, we correlated MODIS albedo and monthly air temperature extracted from the ERA-Interim reanalysis dataset.
Results show that decreasing trends exist with a strong spatial variability in the whole Alpine chain. In large glaciers, such as the Aletch (Swiss Alps), the trend varies significantly also within the glacier, showing that the trend is higher in the area across the accumulation and ablation zone.
Over the 17 glaciers with mass balance available in the WGMS data set, 11 gave significant relationship with the MODIS summer albedo. Moreover, the comparison between ERA-Interim temperature anomalies and albedo anomalies showed significant results, on average two degrees of summer temperature anomaly produced a 20% summer albedo decrease. Nevertheless, the low variance explained by air temperature can suggest that other processes, such as the presence of light-absorbing impurities, can be involved in the observed albedo decrease.