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Varying Snow and Vegetation Signatures of Surface Albedo Feedback on the Northern Hemisphere Land Warming

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Changes in snow and vegetation cover associated with global warming can modify surface albedo (the reflected amount of radiative energy from the sun), therefore modulating the rise of surface temperature that is primarily caused by anthropogenic greenhouse-gases emission. This introduces a series of potential feedbacks to regional warming with positive (negative) feedbacks enhancing (reducing) temperature increase by augmenting (decreasing) the absorption of short-wave radiation. So far our knowledge on the importance and magnitude of these feedbacks has been hampered by the limited availability of relatively long records of continuous satellite observations.

Here we exploit a 31-year (1982-2012) high-frequency observational record of land data to quantify the strength of the surface-albedo feedback on land warming modulated by snow and vegetation during the recent historical period. To distinguish snow and vegetation contributions to this feedback, we examine temporal composites of satellite data in three different Northern Hemisphere domains. The analysis reveals and quantifies markedly different signatures of the surface-albedo feedback. A large positive surface-albedo feedback of +0.87 [CI 95%: 0.68, 1.05] $W/(m^2 \cdot K)$ absorbed solar radiation per degree of temperature increase is estimated in the domain where snow dominates. On the other hand the surface-albedo feedback becomes predominantly negative where vegetation dominates: it is largely negative (-0.91 [-0.81, -1.03] $W/(m^2 \cdot K)$) in the domain with vegetation dominating, while it is moderately negative (-0.57 [-0.40, -0.72] $W/(m^2 \cdot K)$) where both vegetation and snow are significantly present. Snow cover reduction consistently provides a positive feedback on warming. In contrast, vegetation expansion can produce either positive or negative feedbacks in different regions and seasons, depending on whether the underlying surface being replaced has higher (e.g. snow) or lower (e.g. dark soils) albedo than vegetation.

The observational data and analysis from this work is supplying fundamental knowledge to model

and predict how the surface-albedo feedback will evolve and affect the rate of regional temperature rise in the future. So far the simulation and prediction of albedo feedbacks shows a large spread and divergence among the available state-of-the-art Earth System Models (ESMs), due to uncertainties in the representation of vegetation-snow processes and the dynamics of vegetation and to uncertainties in land-cover parameters. By exploiting the unprecedented observational benchmarks to evaluate the ESMs currently engaged in CMIP6, this work will allow an improved and better constrained representation of the processes underlying surface albedo feedbacks in the next generation of ESMs.

This work is in now in Press and Open Access on Environmental Research Letters: https://doi.org/10.1088/1748-9326/abd65f