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Reconciling different approaches to quantifying surface cooling induced by afforestation in China using satellite observations

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Forest cover change can cause strong local biophysical feedbacks on climate. Satellite observations of land surface temperature (T) and land cover distribution or forest cover change have been widely used to examine the effects of afforestation/deforestation on local surface temperature change (ΔT). However, different approaches were used by previous analyses to quantifying ΔT, and it remains unclear whether results of ΔT by these approaches are comparable. We identified three influential approaches to quantifying ΔT used by previous studies, namely the actual ΔT resulting from actual changes in forest coverage over time and accounting for changes in background climate (ΔT_a proposed by Alkama and Cescatti, 2016), potential ΔT by hypothesizing potential shifts between non-forest and forest at given native spatial resolutions of satellite products (ΔT_{p1} by Li et al., 2015), and potential ΔT, but using the singular value decomposition technique to derive ΔT by hypothesizing a shift between a 100% complete non-forest and 100% forest (ΔT_{p2} by Duveiller et al., 2019). China realized large-scale afforestation making it a suitable test case to compare satellite-based approaches for estimating ΔT following afforestation. We hypothesize that (1) ΔT_a depends on the fraction of ground area that's been afforested (F_{aff}). (2) The relative magnitude between different approaches should be: $\Delta T_a < \Delta T_{p1} < \Delta T_{p2}$. (3) When ΔT_a is extended to a hypothetical case that F_{aff} reaches 100%, it should be comparable to ΔT_{p1} or ΔT_{p2}. We used multiple satellite observation products to test these hypotheses. The results show that the magnitude of actual daytime surface cooling by afforestation (ΔT_a) increases with F_{aff}, and is significantly lower than ΔT_{p1} and ΔT_{p2}. But no significant difference was found between ΔT_{p1} and ΔT_{p2}. A linear regression model established between ΔT_a and F_{aff} extends the ΔT_a, when F_{aff} reaches 100%, to a comparable magnitude than ΔT_{p1} and ΔT_{p2}. Our study thus highlights the importance to consider the actual surface cooling impact by afforestation projects in contrast to the potential effects, and provides a first study to reconcile different approaches to quantify the land surface temperature change due to afforestation.