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Warming-induced phenological mismatch between trees and shrubs explains high-elevation forest expansion

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Despite the importance of species interaction in modulating the range shifts of plants, little is known about the responses of coexisting life forms to a warmer climate. Here, we combine long-term monitoring of cambial phenology in sympatric trees and shrubs at two treelines of the Tibetan Plateau, with a meta-analysis of ring-width series from 344 shrubs and 575 trees paired across 11 alpine treelines in the Northern Hemisphere. Under a spring warming of + 1°C, xylem resumption advances by 2–4 days in trees, but delays by 3–8 days in shrubs. The divergent phenological response to warming was due to shrubs being 3.2 times more sensitive than trees to chilling accumulation. Warmer winters increased the thermal requirement for cambial reactivation in shrubs, leading to a delayed response to warmer springs. Our meta-analysis confirmed such a mechanism across continental scales. The warming-induced phenological mismatch may give a competitive advantage to trees over shrubs, which would provide a new explanation for increasing alpine treeline shifts under the context of climate change.