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Improving photosynthesis estimation in northern temperate and boreal forest ecosystems

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The projected extension of growing season length under climate change will increase the carbon uptake potential of forest ecosystems at high latitudes. However, the dynamics of carbon uptake in high latitudes, namely ecosystem scale photosynthesis have not been well represented in existing carbon models yet. This impedes the unbiased assessment of current and predicted carbon dynamics at regional and continental scales. For instance, a substantial overestimation of simulated (by applying a state-of-the-art terrestrial photosynthesis model (P-model)) compared to gross primary productivity (GPP) derived from eddy-covariance (EC) was found in early spring for many sites and years. Here we show a substantial reduction of this GPP overestimation by adding a stress function accounting for the effects of low temperature and high light intensity. We found the strong depression of light use efficiency (LUE) in the GPP overestimation sites, which is related to the high photosynthetic photon flux density (PPFD) and low daily minimum temperatures (T_{min}) during the early spring and preceding weeks or months. This mismatch between modelled and EC-derived GPP can be attributed to the adjustment of leaf properties and photosynthesis, e.g., synthesizing photoprotective pigments while reducing photosynthesis pigments in evergreen trees in the cold periods to protect the photosynthesis apparatus from damage from excessive light (photoprotection). This is supported by the observed high red chromatic coordinates (RCC) and delayed increase of green chromatic coordinates (GCC) from digital repeat photography. Finally, through embedding an empirical stress function considering the direct and lagged impact from T_{min} into the model, we improved the GPP estimation and reduced the model-observation mismatch in GPP in early spring. Our results demonstrate one way to improve the GPP estimation in high latitude ecosystem by taking the physiological processes (e.g. photoprotection) into account. This enables a more accurate estimation of the continental carbon dynamics under climate change.