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Influence of spring phenology on seasonal net primary productivity in the alpine grassland on the Tibetan Plateau

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Vegetation phenology is recognized to exert crucial influences on carbon sequestration and the role of vegetation phenology in mediating carbon cycle varies with ecosystem type. However, the relationship between vegetation phenology and productivity has not been fully understood in the alpine ecosystem due to a lack of field observations, poor model performances and their complex mechanisms. In this study, we examined the spatio-temporal variation in beginning of growing season (BGS) and net primary productivity (NPP) for the alpine grassland on the Tibetan Plateau (TP) and the regulation effects of spring phenology on seasonal NPP by integrating field observations, remote sensing monitoring and ecosystem model simulation. The ecosystem model performances were improved by optimizing ecosystem parameters from field observations. The results indicated a significant advance in BGS with a rate of 0.31 days/yr ($P < 0.1$) in the alpine grassland during 2001-2015 while the annual NPP increased significantly at a rate of 1.25 $gC/m^2/yr$ ($P < 0.01$). With regard to the relationship between BGS and NPP, large spatial heterogeneities were identified. Overall, a negative but non-significant correlation ($R = -0.34$, $P > 0.1$) was observed between BGS and annual NPP for the entire grassland ecosystem on the TP. But responses of NPP to BGS varied with seasons. Specifically, BGS showed significant negative correlation with spring NPP ($R = -0.73$, $P < 0.01$), and advanced spring led to increased spring NPP. The positive effects of advanced BGS on NPP tended to weaken in summer. Moreover, BGS was significantly and positively correlated with autumn NPP in some relatively arid zones of the southwestern TP, suggesting the suppressing effects of earlier spring on carbon assimilation during the later growing season in water limited areas. This study improved our understanding on the impacts of biotic factors on carbon cycles of the alpine ecosystem and implies that the effects of phenology can't be concluded simply for an annual sum, and their relationships for each separate season are also critical.