



Climatic impacts on autumn phenology and the contributor to GSL across the Tibetan Plateau

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Changes in the start and end of vegetation growing season (SOS and EOS) are insightful for assessing ecosystem response to climate change because of the high sensitivity of phenology to the climate and their extensive influences on terrestrial ecological processes. From 1982 to 2011, dramatic climate warming resulted in substantial increases in SOS on the Tibetan Plateau (TP). However, it is unclear how EOS changes during this period. We employed multiple remote sensing methods to estimate EOS and SOS from satellite NDVI, and investigated the relationship between EOS and its drivers. We also conducted an analysis on the contribution of EOS and SOS to the change of growing season length (GSL). It showed that EOS was primarily driven by pre-season temperature, and partly by precipitation and solar insolation. In the southwestern TP, EOS was significantly and positively related with SOS, suggesting a potentially indirect effect of winter meteorological conditions on the following autumn phenology through the regulation of spring phenology. During this period, on average, SOS remarkably advanced by 0.14 day/year ($P = 0.086$), whereas EOS showed only slight and insignificant delay (0.08day/year, $P = 0.140$), implying the regionally averaged extension of GSL was mainly caused by an earlier spring. For spatial pattern, SOS mainly advanced (73%) and EOS primarily delayed (73%). As a result of the variation, 79% of the pixels showed extended GSL, where 67% of them were primarily caused by SOS advance, and the other 33% were mainly caused by EOS delay. Interestingly, areas where the spring was the key factor for GSL extension were mainly distributed in relatively dry western part of TP, and contrarily, autumn contributed more to the GSL were located in the wetter northeastern part. This phenomenon suggests the shifts of GSL are dependent on environmental conditions by the performance SOS and EOS.