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Elucidating climatic controls of polynomial trends in interannual variations of northern ecosystem productivities

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Rapid warming in northern high latitudes during the past two decades may have profound impacts on the structures and functioning of ecosystems. Understanding how ecosystems respond to climatic change is crucial for the prediction of climate-induced changes in plant phenology and productivity. Here we investigate spatial patterns of polynomial trends in ecosystem productivity for northern (> 30 °N) biomes and their relationships with climatic drivers during 2000–2018. Based on a moderate resolution (0.05°) of satellite data and climate observations, we quantify polynomial trend types and change rates of ecosystem productivities using plant phenology index (PPI), a proxy of gross primary productivity (GPP), and a polynomial trend identification scheme (Polytrend). We find the yearly-integrated PPI (PPI_{INT}) shows a high degree of agreement with an OCO-2-based solar induced chlorophyll fluorescence GPP product (GOSIF-GPP) for distinct spatial patterns of trend types of ecosystem productivities. The averaged slope for linear trends of GPP is found positive across all the biomes, among which deciduous broadleaved and evergreen needle-leaved forests show the highest and lowest rates respectively. The evergreen needle-leaved forests, low shrub, and permanent wetland show linear trends in PPI_{INT} over more than 50% of the covered area and permanent wetland also shows a large fraction of the area with the quadratic and cubic trends. Spatial patterns of linear trends for growing season sum of temperature, precipitation, and photosynthetic active radiation have been quantified. Based on the partial correlations between PPI_{INT} and climate drivers, we found that there is a consistent shift of dominant drivers from temperature or radiation to precipitation across all the biomes except the permeant wetland when the trend type of ecosystem productivity changes from linear to non-linear. This may imply precipitation changes in recent years may

determine the linear or non-linear responses of ecosystem productivity to climate change. Our results highlight the importance of understanding how changes in climatic drivers may affect the overall responses of ecosystems productivity. Our findings will facilitate the sustainable management of ecosystems accounting for the resilience of ecosystem productivity and phenology to future climate change.