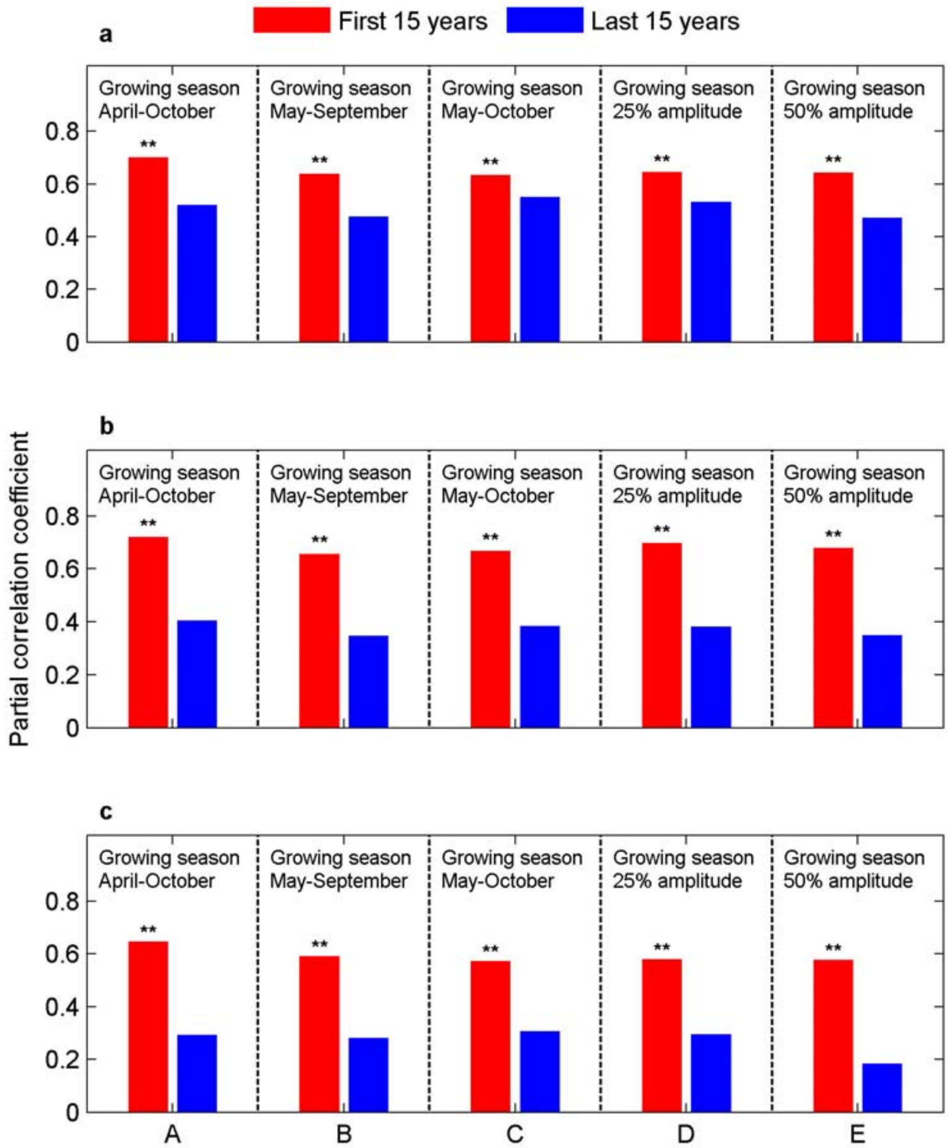
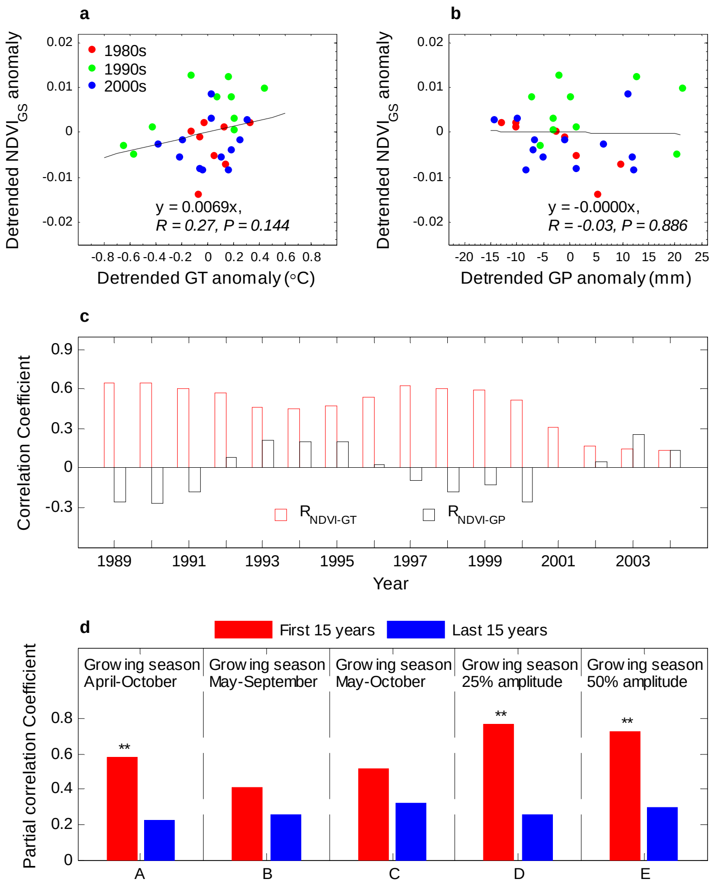
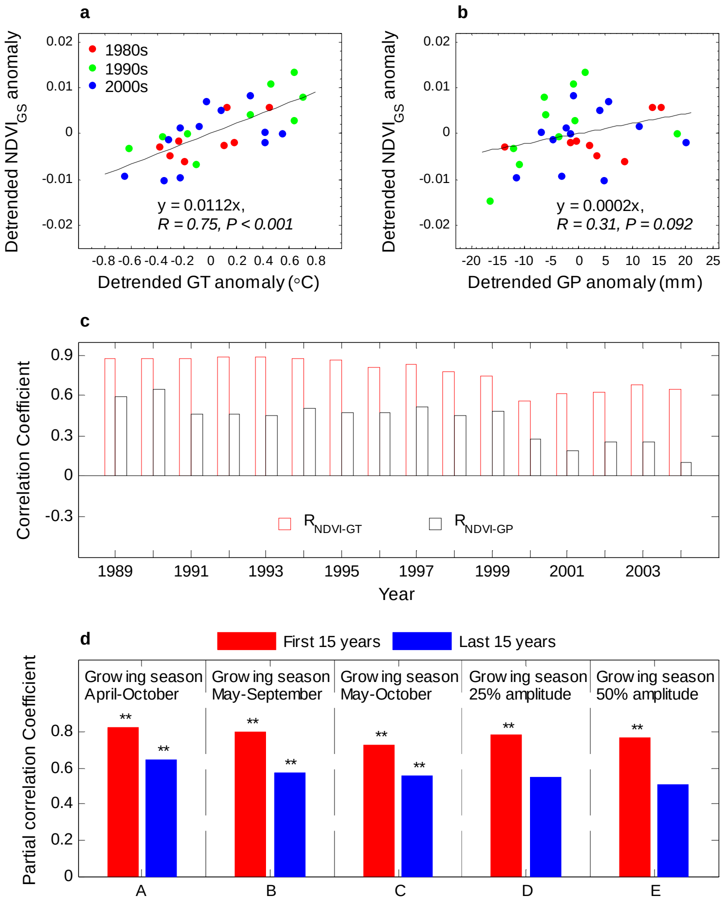
Supplementary Figures



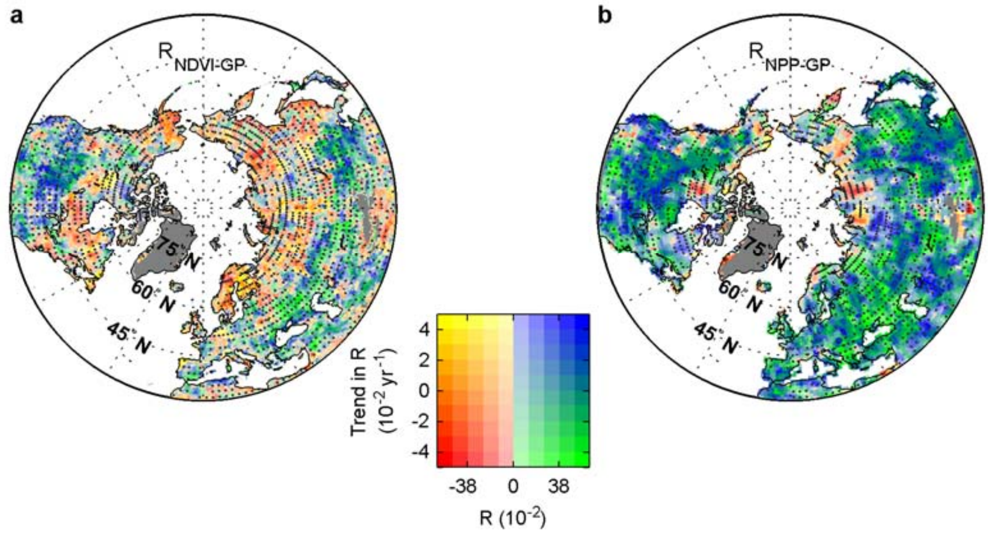
Supplementary Figure 1: The partial correlation coefficient of $NDVI_{GS}$ and GT for the first 15 years (1982-1996) and the last 15 years (1997-2011) with five different definition of growing season. (**a**) All variables are not detrended, (**b**) annual precipitation (the sum of monthly precipitation stretching from previous November to current October) is used as a surrogate for growing season precipitation and (**c**) GIMMS leaf area index (LAI) is used instead of NDVI data.



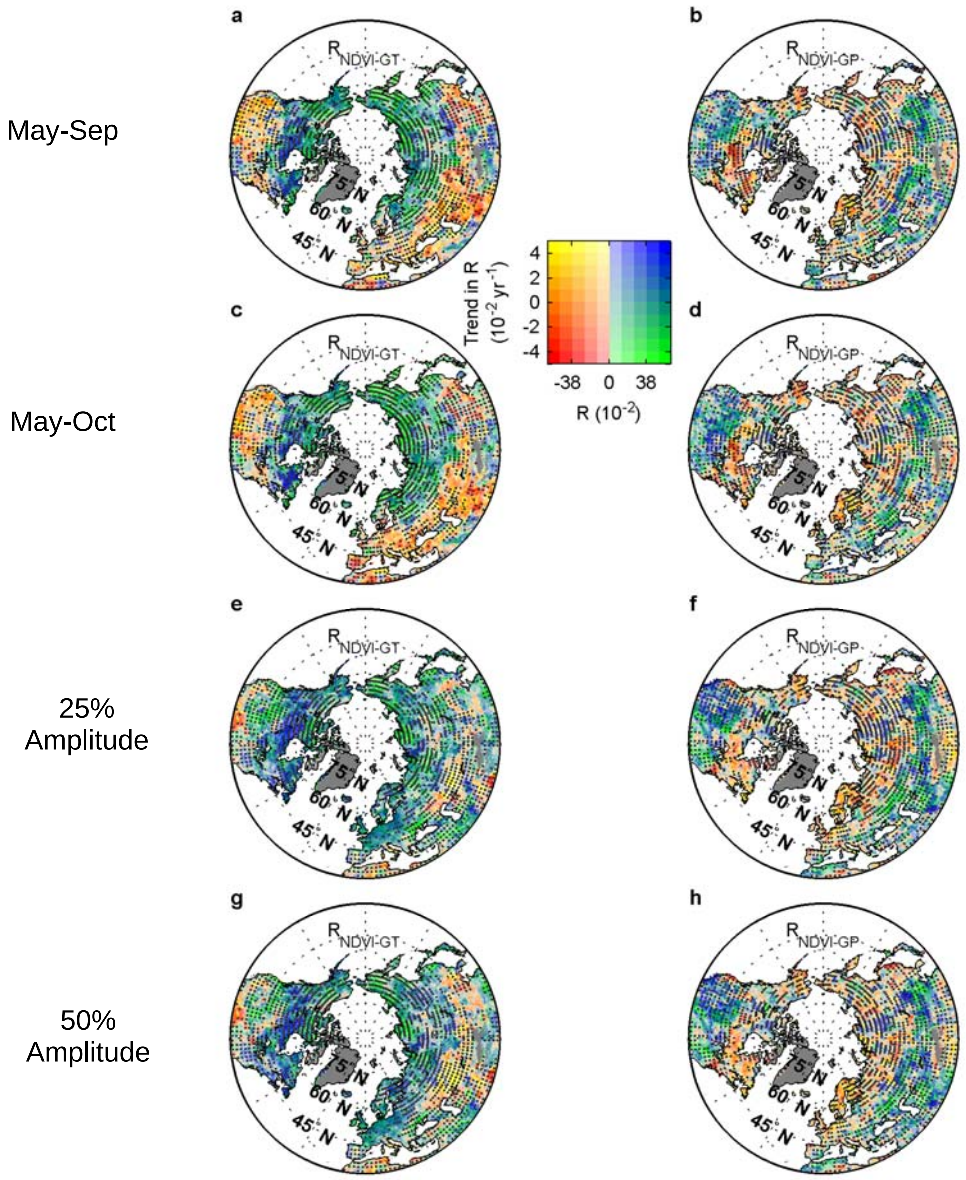
Supplementary Figure 2: The linkage between spatially averaged growing season NDVI ($NDVI_{GS}$) and climate over the latitude band (30 °N-60 °N) during 1982-2011. Relationship of detrended anomalies of $NDVI_{GS}$ with (**a**) growing season temperature (GT), and (**b**) growing season precipitation (GP) for the whole study period of 1982-2011. The lines in (**a**) and (**b**) represent the linear regressions of $NDVI_{GS}$ versus GT (**a**) and GP (**b**). The dots in different color represent observation for the period of 1980s (1982-1989), 1990s (1991-1999) and 2000s (2000-2011), respectively. (**c**) Changes in the correlation coefficient between $NDVI_{GS}$ and GT, and between $NDVI_{GS}$ and GP after applying 15-year moving windows (all variables detrended for each corresponding window). The x-axis is the central year of the 15-year moving window (e.g. 1990 stands for a moving window from 1983-1997). For (**a**)**,** (**b**)**,** and (**c**), growing season is defined as April to October. (**d**) The partial correlation coefficient of $NDVI_{GS}$ and GT for the first 15 years (1982-1996) and the last 15 years (1997-2011) with five different definition of growing season. Growing season is defined as April to October, May to September, May to October, months with NDVI exceeding 25% of its seasonal amplitude and months with NDVI exceeding 50% of its amplitude, respectively. ** indicates a significant correlation at $P < 0.05$.



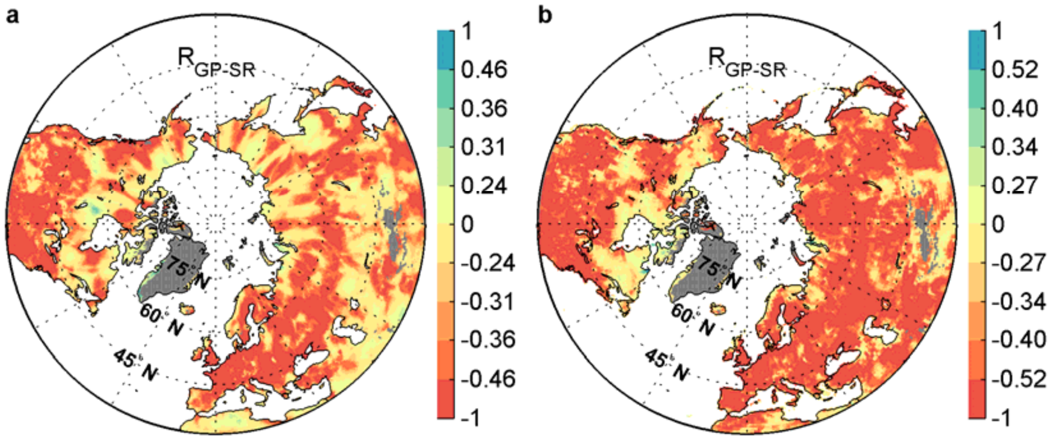
Supplementary Figure 3: The linkage between spatially averaged growing season NDVI ($NDVI_{GS}$) and climate over the latitude band above 60°N during 1982-2011. Relationship of detrended anomalies of $NDVI_{GS}$ with (**a**) growing season temperature (GT), and (**b**) growing season precipitation (GP) for the whole study period of 1982-2011. The lines in (**a**) and (**b**) represent the linear regressions of $NDVI_{GS}$ versus GT (**a**) and GP (**b**). The dots in different color represent observation for the period of 1980s (1982-1989), 1990s (1991-1999) and 2000s (2000-2011), respectively. (**c**) Changes in the correlation coefficient between $NDVI_{GS}$ and GT, and between $NDVI_{GS}$ and GP after applying 15-year moving windows (all variables detrended for each corresponding window). The x-axis is the central year of the 15-year moving window (e.g. 1990 stands for a moving window from 1983-1997). For (**a**), (**b**), and (**c**), growing season is defined as April to October. (**d**) The partial correlation coefficient of $NDVI_{GS}$ and GT for the first 15 years (1982-1996) and the last 15 years (1997-2011) with five different definition of growing season. Growing season is defined as April to October, May to September, May to October, months with NDVI exceeding 25% of its seasonal amplitude and months with NDVI exceeding 50% of its amplitude, respectively. ** indicates a significant correlation at $P < 0.05$.



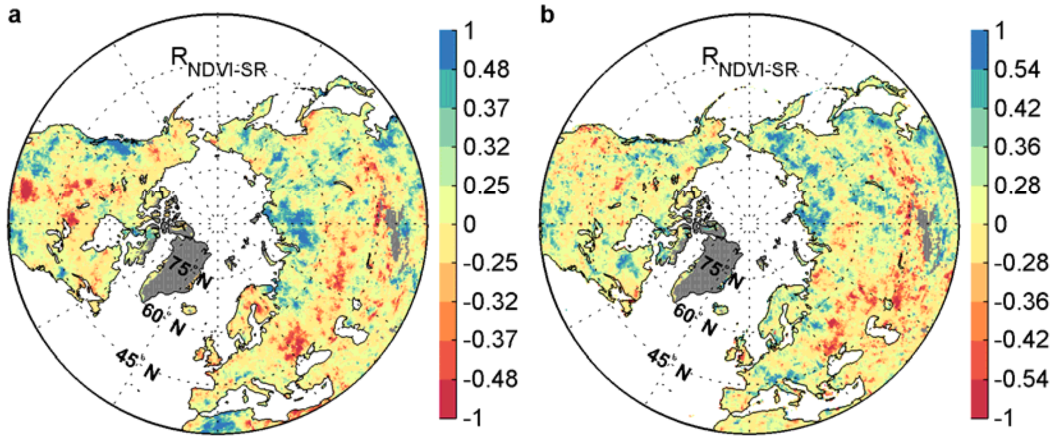
Supplementary Figure 4: Spatial distribution of the partial correlation coefficient (*R*) of vegetation productivity and precipitation, and the trend of *R* over the Northern Hemisphere. (**a**) partial correlation coefficient ($R_{NDVI-GP}$) between growing season NDVI ($NDVI_{GS}$) and growing season precipitation (GP); (**b**) partial correlation coefficient (R_{NPP-GP}) between 10 models estimated average of growing season net primary productivity (NPP_{GS}) and GP. Growing season is defined as April to October. The horizontal axis of the color legend is calculated for the entire study period, and R = ±0.38 corresponds to the 0.05 significance levels for the entire study period. 15-year moving windows are used to estimate the trend of *R* (the vertical axis of the color legend). All variables are detrended for the corresponding period. To calculate its partial correlation versus GP, growing season temperature and cloud cover are controlled for. The dots indicates the regions with significant trend in $R_{NDVI-GP}$ (or R_{NPP-GP}) ($P<0.05$).



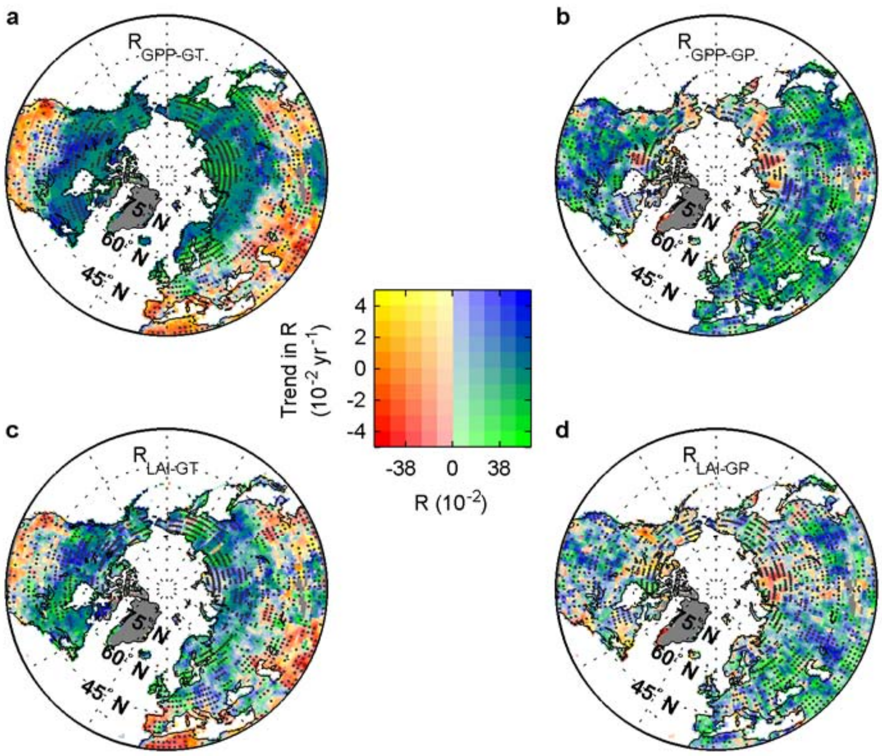
Supplementary Figure 5: **Spatial distribution of the partial correlation coefficient (*R*) of NDVI and climate, and the trend of *R* over the Northern Hemisphere. (a), (c), (e), and (g)** partial correlation coefficient ($R_{NDVI\text{-}GT}$) between NDVI ($NDVI_{GS}$) and temperature (GT) for May-September, May-October, the continuous months with NDVI exceeding 25% of its seasonal amplitude, and months with NDVI exceeding 50% of its amplitude, respectively. **(b), (d), (f), and (h)** partial correlation coefficient ($R_{NDVI\text{-}GP}$) between NDVI ($NDVI_{GS}$) and precipitation (GP) for May-September, May-October, the continuous months with NDVI exceeding 25% of its seasonal amplitude, and months with NDVI exceeding 50% of its amplitude, respectively. The dots indicates the regions with significant trend in $R_{NDVI\text{-}GT}$ (or $R_{NDVI\text{-}GP}$) ($P<0.05$).



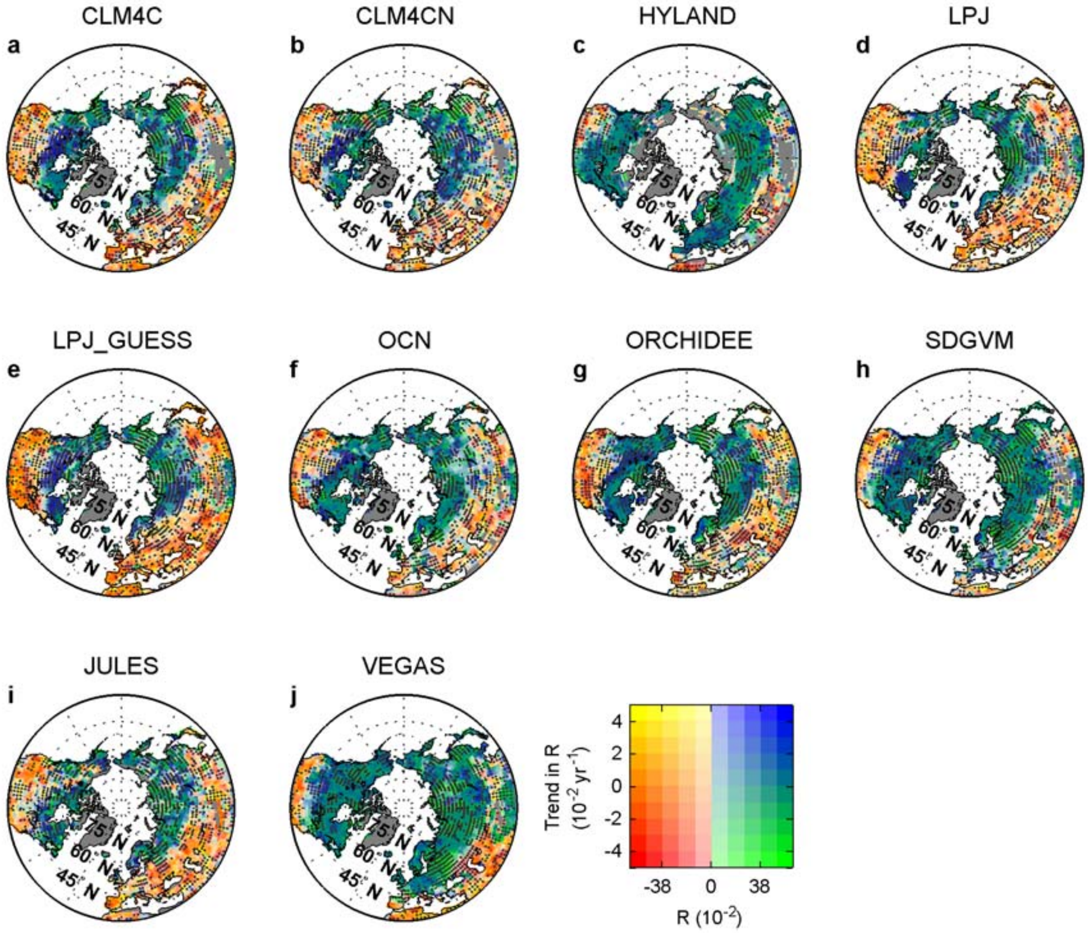
Supplementary Figure 6: **Spatial distribution of correlation coefficient between growing season precipitation (GP) and shortwave solar radiation (SR).** Two different SR datasets are used: (**a**) CRUNECP (http://nacp.ornl.gov/thredds/fileServer/reccapDriver/cru_ncep/analysis/readme.htm) and (**b**) SRB (http://gewex-srb.larc.nasa.gov/common/php/SRB_data_products.php). All variables are detrended for the corresponding period of data availability (1982-2011 for **a** and 1984-2007 for **b**, respectively). Growing season is defined as April to October. In panel (a), R = ±0.46, R = ±0.36, R = ±0.31 and R = ±0.24 correspond to the 0.01, 0.05, 0.1 and 0.2 significance levels, respectively. In panel (b), R = ±0.52, R = ±0.40, R = ±0.34 and R = ±0.27 correspond to the 0.01, 0.05, 0.1 and 0.2 significance levels, respectively.



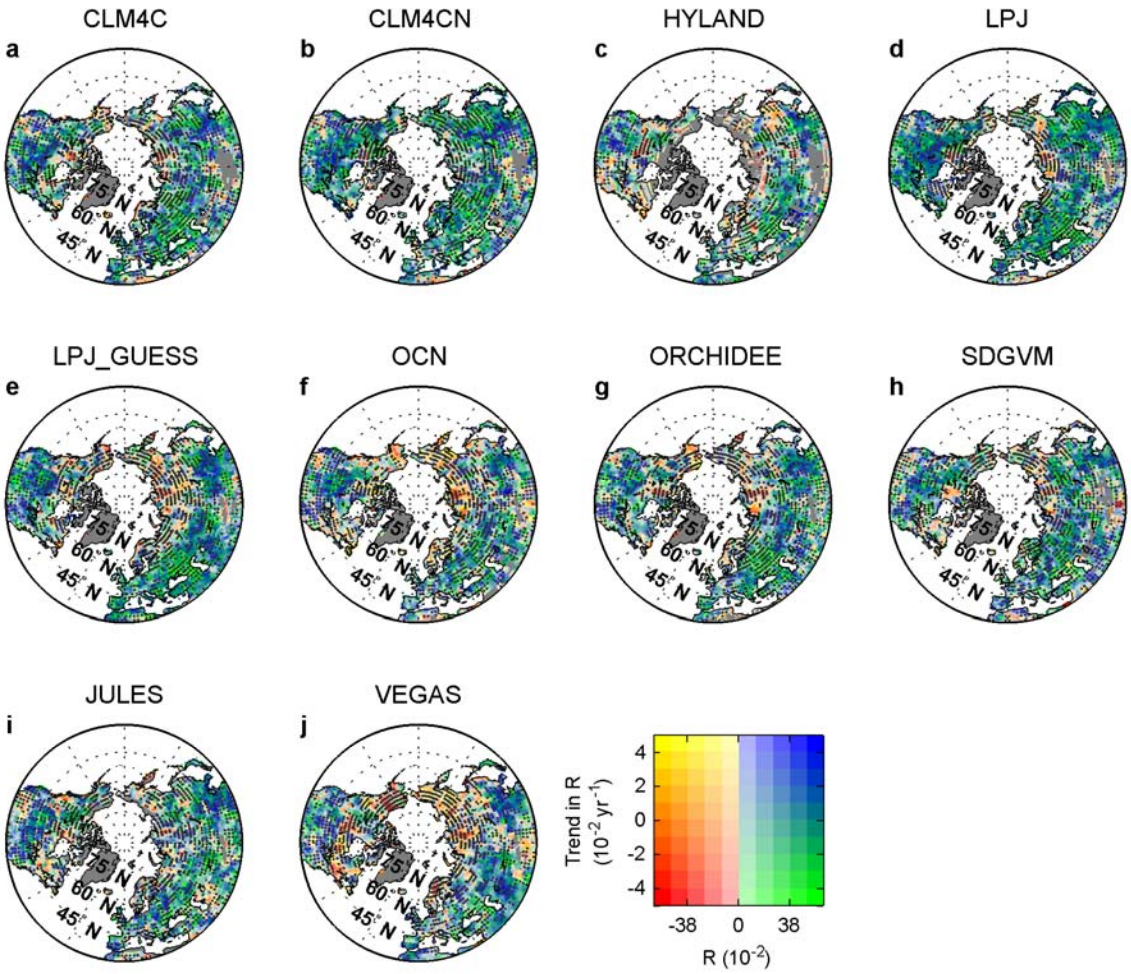
Supplementary Figure 7: **Spatial pattern of partial correlation coefficient between growing season NDVI ($NDVI_{GS}$) and shortwave solar radiation (SR) when statistically controlling for growing season temperature and precipitation.** Two different SR datasets are used: (**a**) CRUNECP (http://nacp.ornl.gov/thredds/fileServer/reccapDriver/cru_ncep/analysis/readme.htm) and (**b**) SRB (http://gewex-srb.larc.nasa.gov/common/php/SRB_data_products.php). All variables are detrended for the corresponding period of data availability (1982-2011 for **a** and 1984-2007 for **b**, respectively). Growing season is defined as April to October. In panel (a), R = ±0.48, R = ±0.37, R = ±0.32 and R = ±0.25 correspond to the 0.01, 0.05, 0.1 and 0.2 significance levels, respectively. In panel (b), R = ±0.54, R = ±0.42, R = ±0.36 and R = ±0.28 correspond to the 0.01, 0.05, 0.1 and 0.2 significance levels, respectively.



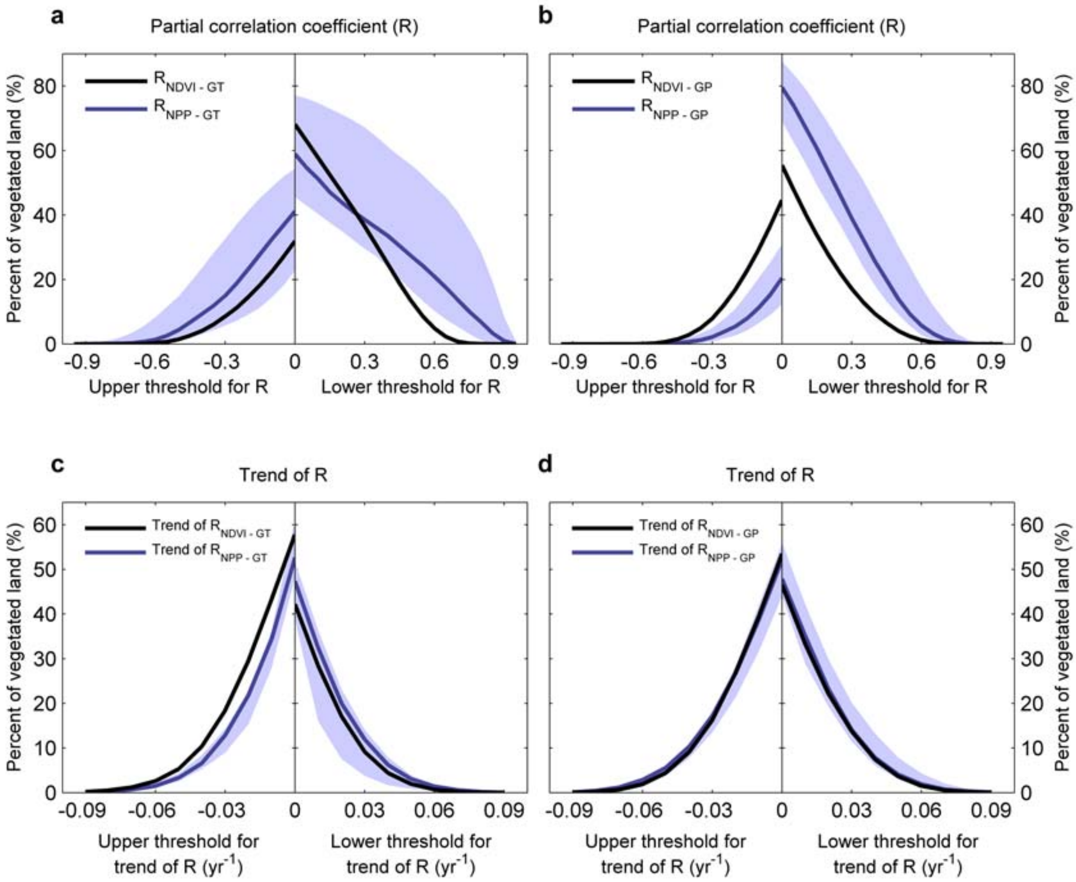
Supplementary Figure 8: Spatial distribution of the partial correlation coefficient (*R*) of vegetation productivity and climate, and the trend of *R* over the Northern Hemisphere. (**a**) partial correlation coefficient ($R_{GPP\text{-}GT}$) between 10 models estimated average of growing season gross primary productivity (GPP_{GS}) and growing season temperature (GT); (**b**) partial correlation coefficient ($R_{GPP\text{-}GP}$) between 10 models estimated average of GPP_{GS} and growing season precipitation (GP); (**c**) partial correlation coefficient ($R_{LAI\text{-}GT}$) between 10 models estimated average of growing season gross LAI (LAY_{GS}) and GT; (**d**) partial correlation coefficient ($R_{LAI\text{-}GP}$) between 10 models estimated average of LAI_{GS} and GP. Growing season is defined as April to October. All variables are detrended for the corresponding period. The dots indicates the regions with significant trend in *R* ($P<0.05$).



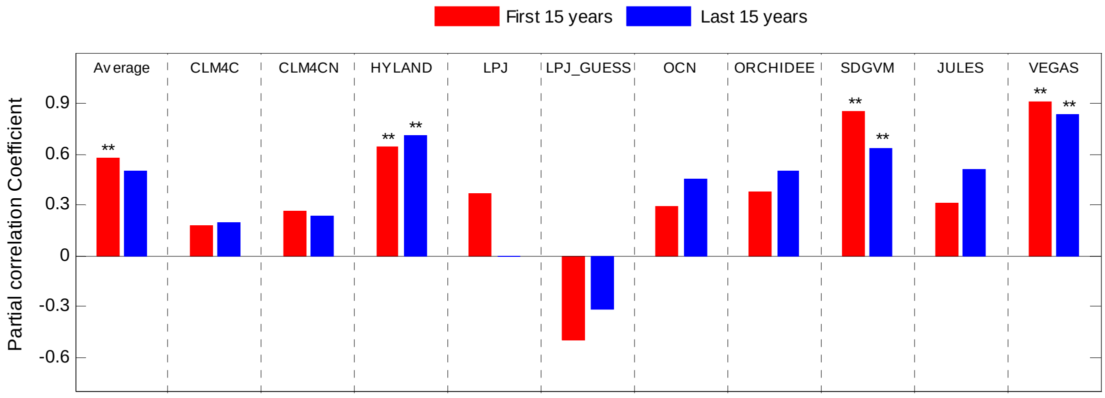
Supplementary Figure 9: Spatial distribution of the partial correlation coefficient ($R_{NPP\text{-}GT}$) of growing season net primary productivity (NPP) and growing season temperature (GT), and the trend of $R_{NPP\text{-}GT}$ over the Northern Hemisphere. Growing season is defined as April to October. All variables are detrended for the corresponding period. The dots indicates the regions with significant trend in $R_{NPP\text{-}GT}$ ($P<0.05$).



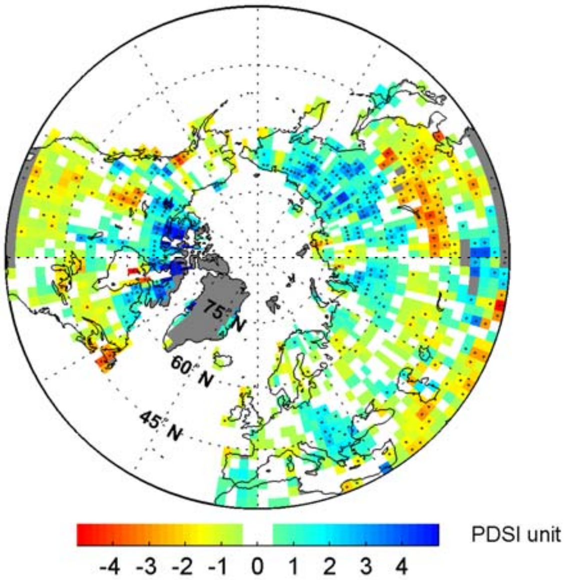
Supplementary Figure 10: Spatial distribution of the partial correlation coefficient ($R_{NPP\text{-}GT}$) of growing season net primary productivity (NPP) and growing season precipitation (GP), and the trend of $R_{NPP\text{-}GP}$ over the Northern Hemisphere. Growing season is defined as April to October. All variables are detrended for the corresponding period. The dots indicates the regions with significant trend in $R_{NPP\text{-}GP}$ ($P<0.05$).



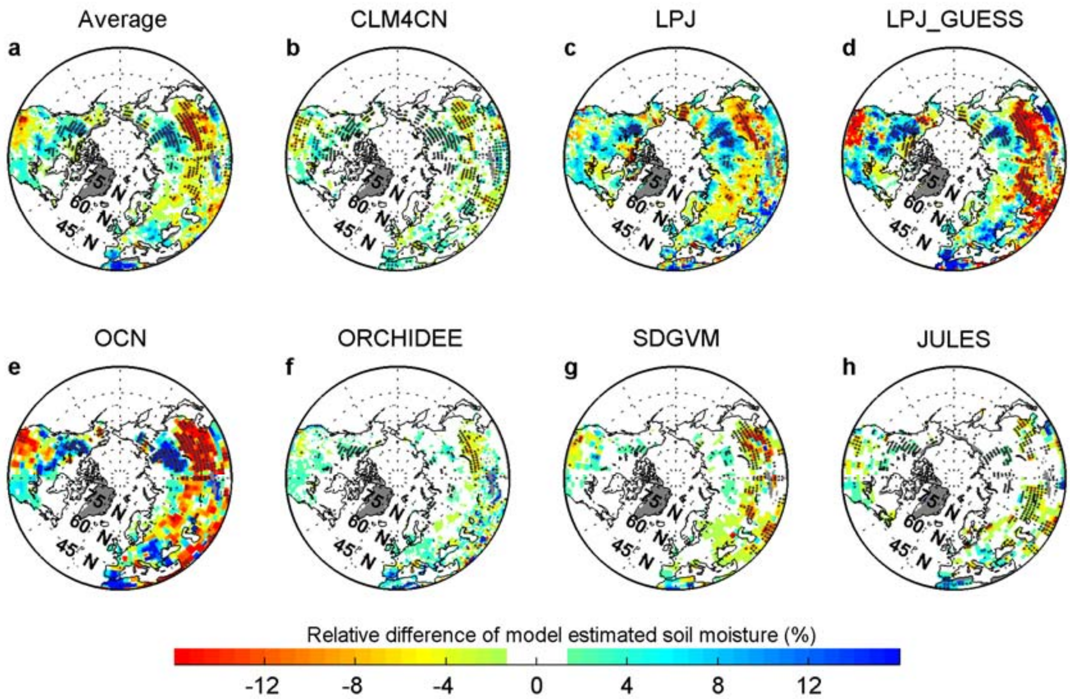
Supplementary Figure 11: Percentage of vegetated land with (a-b) the partial correlation coefficient (*R*) and (c-d) its trend, shown in Figure 2, exceeding the chosen threshold. (**a** and **c**) *R* between growing season NDVI ($NDVI_{GS}$) or model estimated growing season net primary production (NPP_{GS}) and growing season temperature (GT); (**b** and **d**) *R* between $NDVI_{GS}$/ NPP_{GS} and growing season precipitation (GP). The blue area represents the range of the model estimation; the blue line represents the median of it.



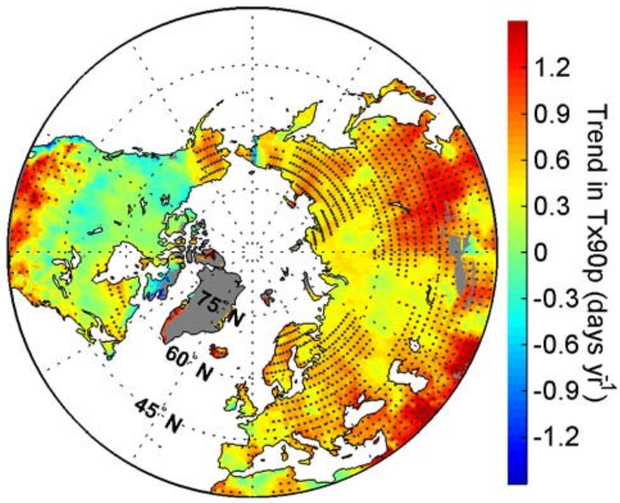
Supplementary Figure 12: **The partial correlation coefficient (R_{NPP-GT}) between spatially averaged growing season net primary productivity (NPP_{GS}) and temperature (GT) for the first 15 years (1982-1996) and the last 15 years (1997-2010) over north of 30°N**. Growing season is defined as April-October.



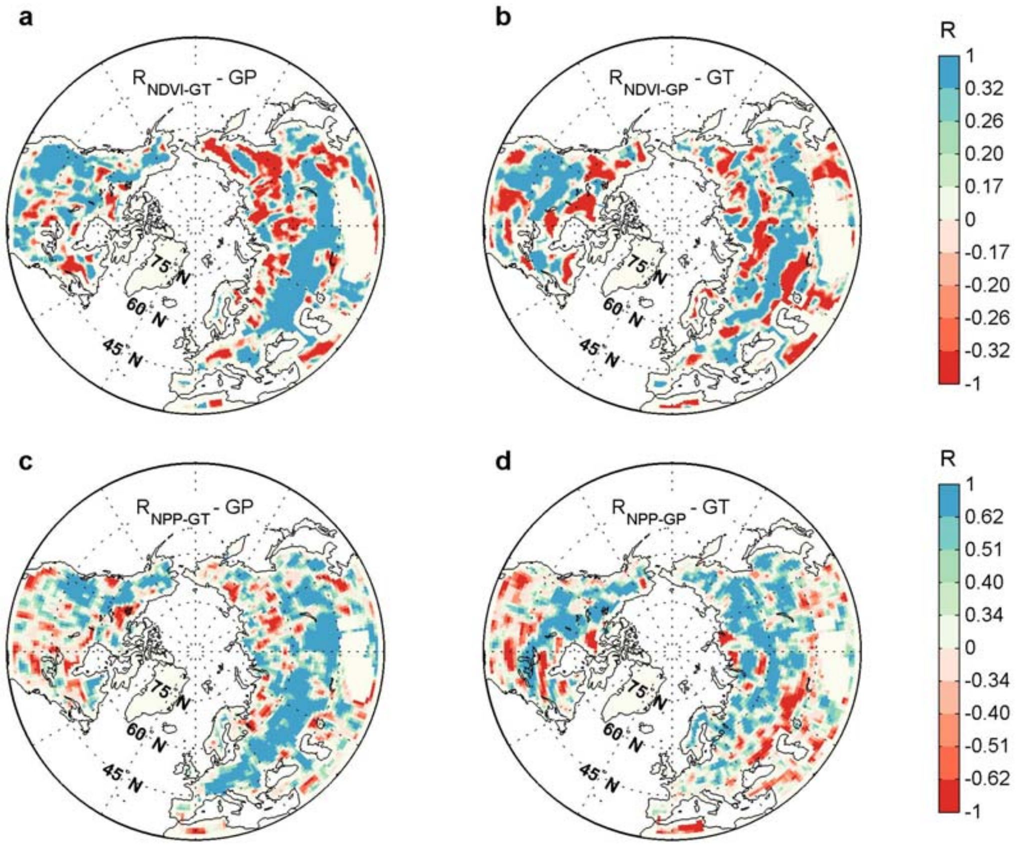
Supplementary Figure 13: Spatial distribution of the difference in the growing season Palmer Drought Severity Index (PDSI) between 1997-2010 and 1982-1996 over the Northern Hemisphere (North of 30° N) (negative values indicate drier condition). Because PDSI data were not available for the year of 2011, we used the mean value of 1997-2010 as that of the last moving window (1997-2011) in the NDVI correlation analysis. The dot indicates the regions with statistically significant difference ($P<0.05$).



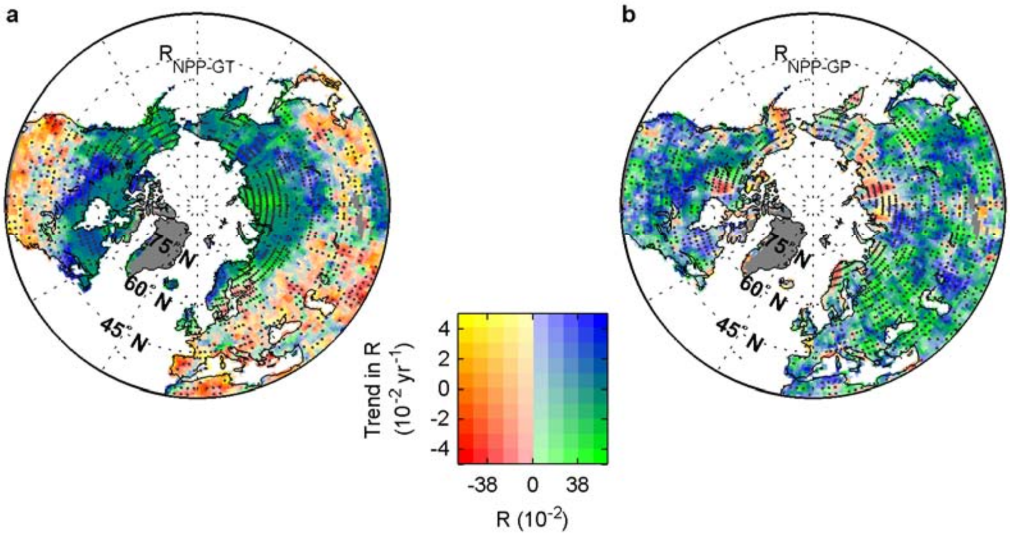
Supplementary Figure 14: Spatial distributions of the relative difference in model simulated growing season soil moisture between 1996-2010 and 1982-1996 (negative values indicate decrease in moisture). The dot indicates the regions with statistically significant difference ($P<0.05$).



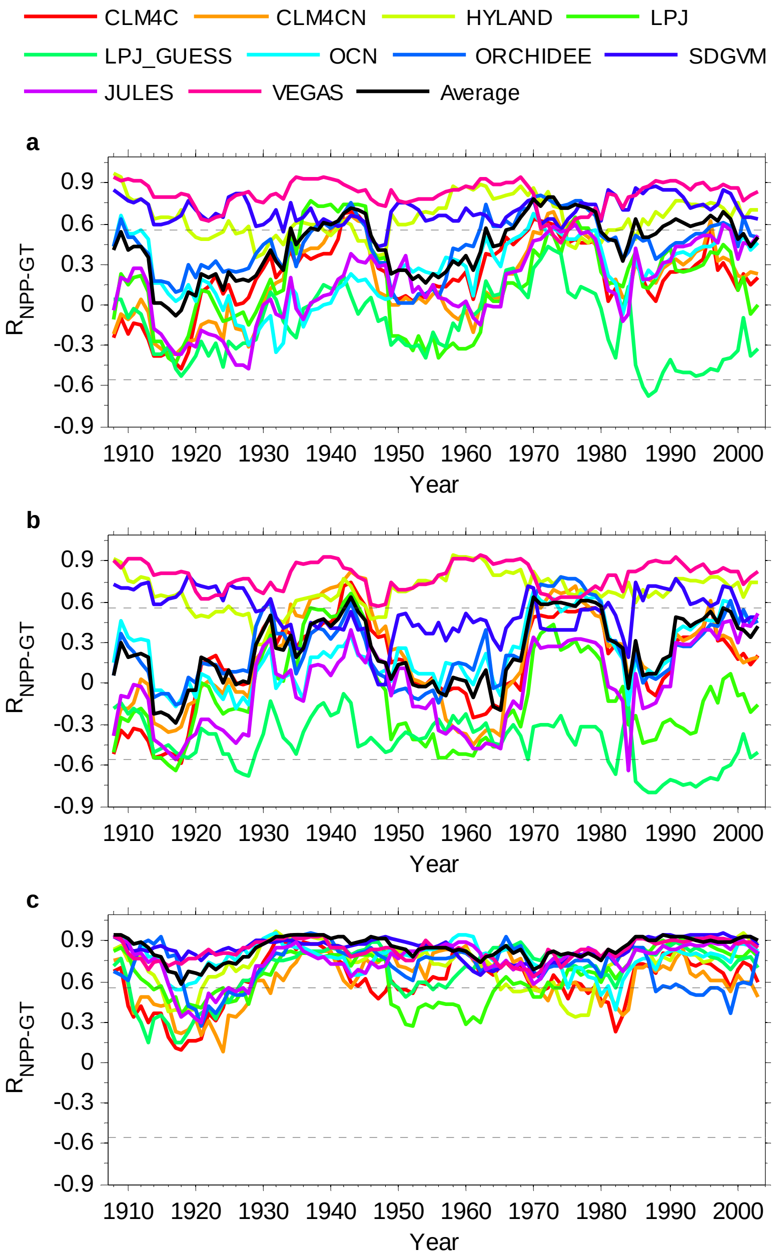
Supplementary Figure 15: Spatial distributions of trend in number of growing season (April to October) hot extreme days from 1982 to 2011. The hot extreme days are defined as the 90th percentile warm day frequency (Tx90p, i.e. the number of days above the 90th percentile) based on whole study period of 1982-2011. The dot indicates the regions with significant trend in Tx90p ($P<0.05$).



Supplementary Figure 16: Spatial distribution of the correlation coefficient between the partial correlation coefficient from Figure 2 and corresponding local climate after applying a moving 5^{o} by 5^{o} spatial window. (**a**) The correlation coefficient between $R_{NDVI\text{-}GT}$ and GP; (**b**) The correlation coefficient between $R_{NDVI\text{-}GP}$ and GT; (**c**) The correlation coefficient between $R_{NPP\text{-}GT}$ and GP; (**d**) The correlation coefficient between and $R_{NPP\text{-}GP}$ and GT. Growing season is defined as April to October. For **a** and **b**, R = ±0.32, R = ±0.26 ,R = ±0.20 and R = ±0.17 correspond to the 0.001, 0.01, 0.05 and 0.10 significance levels, respectively. For **c** and **d**, R = ±0.62, R = ±0.51 ,R = ±0.40 and R = ±0.34 correspond to the 0.001, 0.01, 0.05 and 0.10 significance levels, respectively.



Supplementary Figure 17: Spatial distribution of the partial correlation coefficient (*R*) of growing season net primary productivity (NPP_{GS}) and climate, and the trend of *R* over the Northern Hemisphere. (a) partial correlation coefficient (R_{NPP-GT}) between 10 models estimated average of growing season net primary productivity (NPP_{GS}) and growing season temperature (GT); **(b)** partial correlation coefficient (R_{NPP-GP}) between 10 models estimated average of NPP_{GS} and growing season precipitation (GP). NPP_{GS} computed by subtracting NPP_{GS} of S1 scenario (simulation driven by historical change in atmospheric CO_2 concentration) from NPP_{GS} of S2 scenario (simulation driven by historical change in climate and atmospheric CO_2 concentration). The dot indicates the regions with statistically significant difference ($P<0.05$).



Supplementary Figure 18: Partial correlation coefficient ($R_{NPP\text{-}GT}$) between Trendy models estimated growing season net primary productivity (NPP_{GS}) and growing season temperature (GT) over (a) 30°N-90°N, (b) 30°N-60°N and (c) 60°N-90°N regions for each 15-year moving window during the period 1901-2010. All variables are detrended for each moving window with a linear fit. The horizontal dash line indicates R = 0.55 corresponding to a 0.05 significance level for a 15-year moving window assuming independent yearly data.