Trends in satellite observed circumpolar photosynthetic activity from 1982-2003: The influence of seasonality, cover type and vegetation density

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Overview: Temperature increases in the northern high latitudes over the past few decades have led to a wide variety of ecosystem changes, including modification of the productivity of plants (growth) and associated changes in global CO₂ exchange. Well-known studies of “greening” trends between 1982 and 1991 in high latitude vegetation indicate an earlier onset of growing season and more active photosynthesis in the mid-summer months. Our recent work indicates that these trends do not continue uniformly in time or space but instead vary between vegetation types and different periods of the growing season. The results provide some of the first evidence that high latitude forests may be in decline following an initial growth spurt associated with rising CO₂ and warming. Although the observational time scales are not as long as desired, there is evidence that ecosystem responses have been rapid, even accounting for lags in tree growth to recent climate. The satellite observations are supported by a range of field observations, and indicate that natural ecosystems may be responding to climate change in unexpected ways that could have significant further effects on the biosphere. The results also underscore the need for an expanded observational network, additional analysis of existing data sets (e.g., tree rings), and improvements in process models of ecosystem responses to climate change.

Related Publications


Data set: GIMMS-NDVI Version-G 8x8 km http://glcf.umiacs.umd.edu
MODIS Canopy Density 500x500 m http://glcf.umiacs.umd.edu
All data sets were reprojected to a stereographic polar projection and resampled to 8x8 km

Time series of relative photosynthetic activity (Pg), derived from the GIMMS-NDVI data set, for North America land areas above 50° N showing strong seasonal variation (A) and substantial interannual variation in growing season average Pg (B). Overall, the strong greening trend seen in the first half of the record (1982-1991) is not replicated in the second half, even after accounting for the effects of the 1991 Mt Pinatubo eruption and specifically considering only those areas that have remained unburned since the 1950’s.

Most of the high latitude areas shows no significant trend in photosynthetic activity over the May-August growing season (top), however, significant deterministic trends, as determined using a Violin test, are shown to land cover type and tree canopy density. The areas are colored according to the magnitude of the trends over time with ‘greening’ areas shown in red and yellow and ‘browning’ areas shown in shades of blue. MODIS Canopy Density and the GLC2000 land cover are shown on the bottom for illustration of the distribution of trends.

Trends from the May-August growing season are shown with higher-resolution imagery (30m Landsat-ETM) at three locations with characteristic trend patterns. Areas with significant trends are shown in red and yellow, and areas with opposite trends are shown in blue. The upper left image shows the widespread greening occurring on the tundra areas north of the Brooks Range in Alaska. In the upper right subset shows negative trends in the interior forests of Alaska, while the bottom image shows a transition from positive to negative trends in a boundary from forest to wetlands.

Areas of circumpolar time series models of significant trends in Pg for these time windows (Millions of hectares). Percentages may not sum to 100% due to rounding.

<table>
<thead>
<tr>
<th>No trend</th>
<th>May-Aug</th>
<th>May-June</th>
<th>May-July</th>
<th>May-August</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>277 (12%)</td>
<td>261 (11%)</td>
<td>255 (9%)</td>
<td>267 (11%)</td>
</tr>
<tr>
<td>Negative</td>
<td>60 (3%)</td>
<td>36 (2%)</td>
<td>176 (9%)</td>
<td>162 (9%)</td>
</tr>
</tbody>
</table>

Image of Pg trends across North America, with inset images showing line graphs of Pg corresponding to the maps. Features included in the line graphs include areas of either positive or negative slopes are shown as text in each panel in millions of hectares. These results show that early summer “greening” is replaced by late summer “browning” in forests, whereas tundra areas are ubiquitously “greening.”

The spatial distribution of photosynthetic activity trends changed markedly for the early (May and June) vs. late (July and August) period of the growing season with more “browning”, negative trends, seen in forests during the late period. Compare these results with the land cover and canopy density images shown above.

"Violin" plots show the distribution of significant trends (x axis) for major forest (top row) and low growing vegetation (bottom row) types. Each panel is stratified by growing season window (y axis). Areas of either positive or negative slopes are shown as text in each panel in millions of hectares. These results show that early summer “greening” is replaced by late summer “browning” in forests, whereas tundra areas are ubiquitously “greening.”

The distribution of significant trends (x axis) for the early part of the growing season (top row) and the later part of the growing season (bottom row) by forest type (columns). Each panel is further stratified by forest density (y axis) and areas of either positive or negative slopes are shown as text in each panel in millions of hectares. These indicate that late summer “browning” increases with forest density. This is particularly evident in Russia’s extensive larch forests.