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Satellite remote sensing of terrestrial freeze-thaw state and its effect on northern vegetation productivity and land-atmosphere carbon exchange

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Global satellite remote sensing records show evidence of recent vegetation greening and an advancing growing season at high latitudes. We utilized daily time series, satellite microwave remote sensing observations from the Special Sensor Microwave Imager (SSM/I) to detect the timing of seasonal thawing, freeze-up and duration of the non-frozen period across the pan-Arctic basin and Alaska. We compared these observations with seasonal anomalies in atmospheric CO_2 concentrations from NOAA CMDL northern ($>50^{\circ}$N) monitoring stations and regional patterns of photosynthetic leaf area (LAI) and vegetation net primary production (NPP) from the NOAA AVHRR pathfinder record. The SSM/I derived timing of the primary springtime thaw event was well correlated ($P \leq 0.009$) with annual anomalies in LAI and NPP. The SSM/I derived timing of spring thaw also corresponded strongly with the timing and magnitude of the seasonal drawdown of atmospheric CO_2 in spring and summer. Annual variability in springtime thaw was on the order of ± 7 days, with corresponding impacts to annual productivity of approximately 1% per day. Years with relatively early seasonal thawing showed generally greater annual productivity and terrestrial sink strength for atmospheric carbon, while years with delayed seasonal thawing showed corresponding reductions in canopy cover, annual productivity and terrestrial carbon sequestration. The apparent sensitivity of boreal forest and tundra to springtime thaw indicates that a recent advance of the pan-arctic seasonal thaw cycle and associated lengthening of the potential period of photosynthesis in spring is sufficient to account for the direction and magnitude of the positive vegetation productivity trend for northern ecosystems.

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