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30-year Northern Hemisphere Freeze/Thaw seasonal trends and associated impacts to vegetation growing seasons and Carbon Exchange

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Abstract: Landscape freeze-thaw (F/T) status is closely linked to vegetation phenology and land-atmosphere trace gas exchange where seasonal frozen temperatures are a major constraint to plant growth. We applied a temporal classification of 37 GHz brightness temperature (Tb) series from the Scanning Multichannel Microwave Radiometer (SSMR) and Special Sensor Microwave Imager (SSMI) to classify daily Tb values over global land areas where seasonal frozen temperatures influence ecosystem processes. A temporally consistent, long-term (>30 year) F/T record was created ensuring cross-sensor consistency through pixel-wise adjustment of the SSMR Tb record based on empirical analyses of overlapping SSMR and SSM/I measurements. The resulting F/T record showed mean annual spatial classification accuracies of 91 (±8.6) percent for PM and 84 (±9.3) percent for AM overpass retrievals relative to in situ air temperature measurements from the global weather station network. The F/T results were also compared against other measures of biospheric activity including satellite (MODIS) vegetation greenness (NDVI) and tower CO2 flux measurement based GPP & NEE records at selected FLUXNET sites within the Northern Hemisphere domain. The landscape F/T status was classified from daily (AM & PM) Tb retrievals from SSMR and SSM/I time series using a seasonal threshold approach (STA). The STA was a dynamic threshold defined annually on a grid cell-wise basis from empirical relations established between Tb retrievals and global model reanalysis (NCEP) based air temperature (°C above or below freezing). The STA based F/T classifications are comprised of daily Tb series to define Frozen (AM & PM), Non-frozen (AM & PM), Transitional (AM frozen; PM thawed) and Inverse-Transitional (AM thawed; PM frozen) conditions.

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F/T linkages to C-flux and NDVI patterns at FLUXNET sites: The latitudinal variation in mean r values (0.59-0.72) between summer NDVI and non-frozen period is associated with increasing greenness (NDVI) and active CO2 uptake; whereas shorter non-frozen seasons promote the opposite response. In other areas a lengthening non-frozen season coincides with increased CO2 uptake (NEE) and vegetation productivity (NDVI), and decreased water stress (Tb). The northern non-frozen period (0.189 days yr-1), largely driven by earlier onset of thawing and associated delay in freeze-up, and consistent with global warming. The number of transitional F/T days is generally increasing with warming, but decreasing at lower latitudes and elevations.

Conclusions: The merged (SSMR/SSMI) 30-yr F/T record shows mean annual classification accuracies of 91 (±1.0) and 84 (±0.9) percent for PM and AM overpass retrievals relative to in situ weather station records; the record significantly responds to pre-1980s climate warming trends. The F/T record shows significant (P<0.001) long-term trends in non-frozen period (0.189 days yr-1), largely driven by earlier onset of thawing and associated delay in freeze-up, and consistent with global warming. The number of transitional F/T days is generally increasing with warming, but decreasing at lower latitudes and elevations.

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