Improving the representation of Arctic photosynthesis in Earth System Models

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The primary goal of Earth System Models (ESMs) is to improve understanding and projection of future global change. In order to do this models must accurately represent the terrestrial carbon cycle. Although Arctic carbon fluxes are small relative to global carbon fluxes, uncertainty is large. Photosynthetic CO_2 uptake is well described by the Farquhar, von Caemmerer and Berry (FvCB) model of photosynthesis and most ESMs use a derivation of the FvCB model to calculate gross primary productivity. Two key parameters required by the FvCB model are an estimate of the maximum rate of carboxylation by the enzyme Rubisco ($V_{c,max}$) and the maximum rate of electron transport (J_{max}). In ESMs the parameter $V_{c,max}$ is typically fixed for a given plant functional type (PFT). Only four ESMs currently have an explicit Arctic PFT and the data used to derive $V_{c,max}$ in these models relies on small data sets and unjustified assumptions. We examined the derivation of $V_{c,max}$ and J_{max} in current Arctic PFTs and estimated $V_{c,max}$ and J_{max} for a range of Arctic PFTs growing on the Barrow Environmental Observatory, Barrow, AK. We found that the values of $V_{c,max}$ currently used to represent Arctic plants in ESMs are 70% lower than the values we measured, and contemporary temperature response functions for $V_{c,max}$ also appear to underestimate $V_{c,max}$ at low temperature. ESMs typically use a single multiplier (JV_{ratio}) to convert $V_{c,max}$ to J_{max}, however we found that the JV_{ratio} of Arctic plants is higher than current estimates suggesting that Arctic PFTs will be more responsive to rising carbon dioxide than currently projected. In addition we are exploring remotely sensed methods to scale up key biochemical (e.g. leaf N, leaf mass area) and physiological (e.g. $V_{c,max}$ and J_{max}) properties that drive model representation of photosynthesis in the Arctic. Our data suggest that the Arctic tundra has a much greater capacity for CO_2 uptake, particularly at low temperature, and will be more CO_2 responsive than is currently represented in ESMs. As we build robust relationships between physiology and spectral signatures we hope to provide spatially and temporally resolved trait maps of key model parameters that can be ingested by new model frameworks, or used to validate emergent model properties.