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Climate change impacts on CO2 and CH4 exchange in an Arctic polygonal tundra depend on changes in vegetation and drainage

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Model projections of CO_2 and CH_4 exchange in Arctic tundra during the next century diverge widely. In this modelling study, we used ecosys to examine how climate change will affect CO_2 and CH_4 exchange through its effects on net primary productivity (NPP), heterotrophic respiration (R_h) and thereby on net ecosystem productivity (NEP) in landform features (troughs, rims, centers) of a coastal polygonal tundra landscape at Barrow AK. The model was shown to simulate diurnal and seasonal variation in CO_2 and CH_4 fluxes associated with those in air and soil temperatures (T_a and T_s) and soil water contents (q) under current climate in 2014 and 2015. During RCP 8.5 climate change from 2015 to 2085, rising T_a, atmospheric CO_2 concentrations (C_a) and precipitation (P) increased NPP from 50 – 150 g C m^{-2} y^{-1}, consistent with current biometric estimates, to 200 – 250 g C m^{-2} y^{-1}, depending on feature elevation. Concurrent increases in R_h were slightly smaller, so that net CO_2 exchange rose from values of -25 (net emission) to +50 (net uptake) g C m^{-2} y^{-1} to ones of -10 to +65 g C m^{-2} y^{-1}, again depending on feature elevation. Large increases in R_h with thawing permafrost were not modelled. Increases in net CO_2 uptake were largely offset by increases in CH_4 emissions from 0 – 6 g C m^{-2} y^{-1} to 1 – 20 g C m^{-2} y^{-1}, depending on feature elevation, reducing gains in NEP. Increases in CH_4 emissions with climate change were mostly attributed to increases in T_a, but also to increases in C_a and P. These increases in net CO_2 uptake and CH_4 emissions were modelled with hydrological boundary conditions that were assumed not to change with climate. Both these increases were smaller if boundary conditions were gradually altered to increase landscape drainage during model runs with climate change. The model was then applied to the entire permafrost zone of North America to project RCP 8.5 climate change effects on active layer depth and ecosystem productivity by 2100.