Partitioning changes to the Arctic carbon budget in future RCP scenarios

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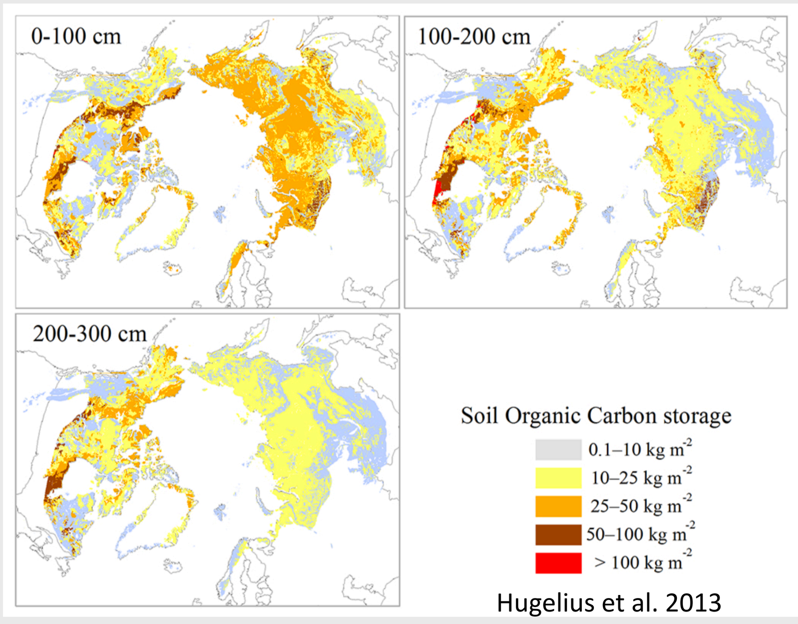
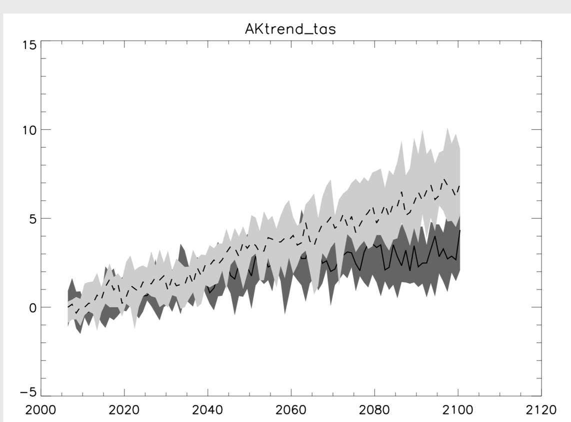
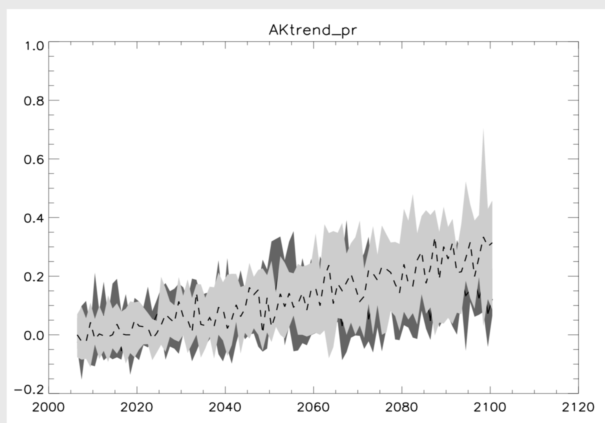
Motivation: Arctic Carbon Release

The arctic has vast amounts of carbon stored in the soil, much of which is locked in permafrost and protected from respiration.

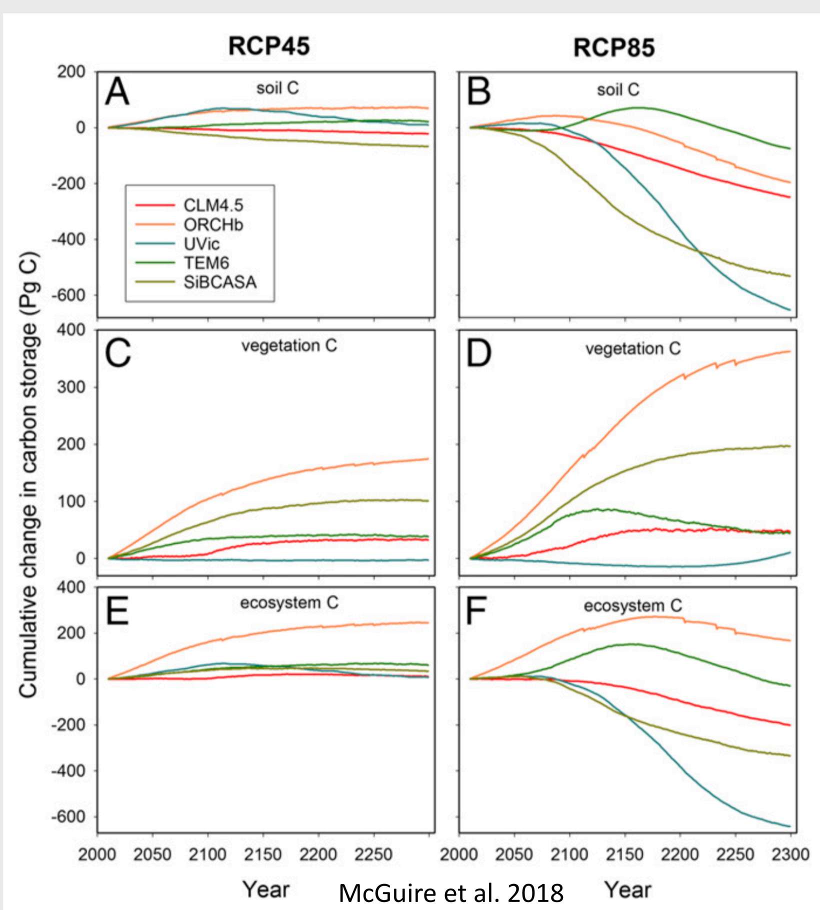




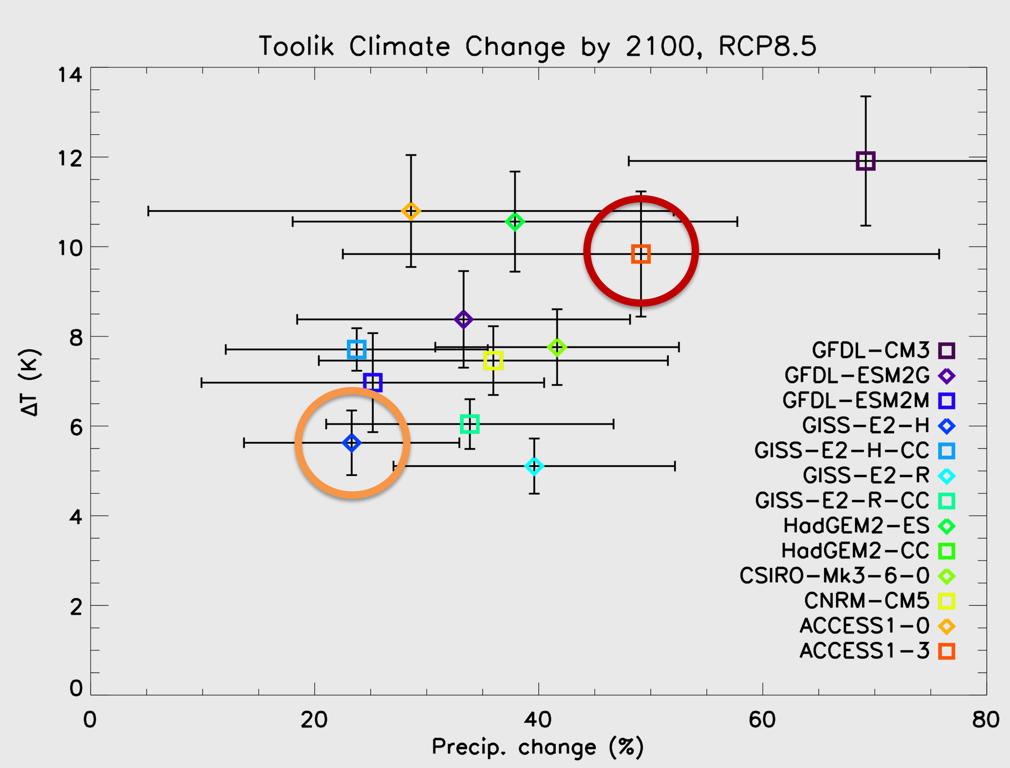


However, this carbon may become accessible as temperature (K) and precipitation (fraction) change in the future. Here are the RCP8.5 and RCP4.5 scenarios for the Alaskan tundra.

The competing mechanisms of enhanced plant growth and enhanced respiration have opposite effects on the net carbon budget. Due to complex nonlinear interactions, it is not obvious which mechanism will dominate in a warming world. Here several models disagree on the sign of the net carbon change in the Arctic.

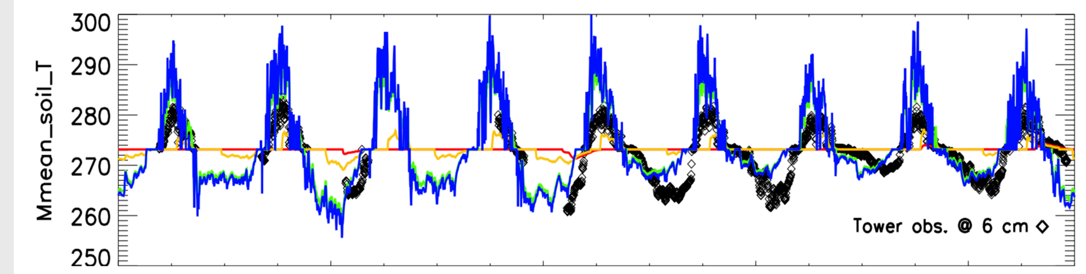


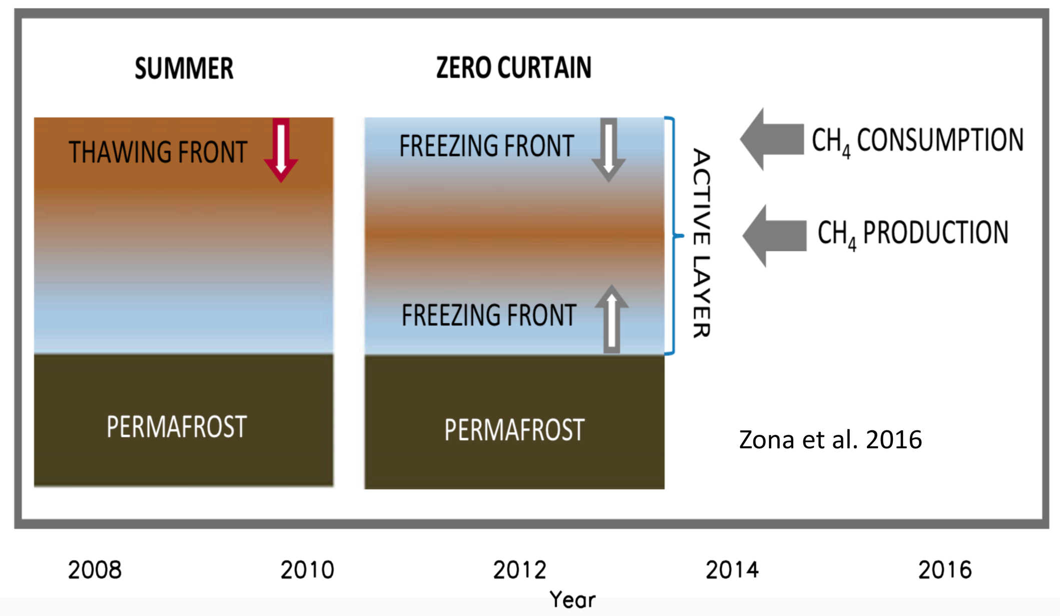
RCP8.5 Warm and Hot scenarios

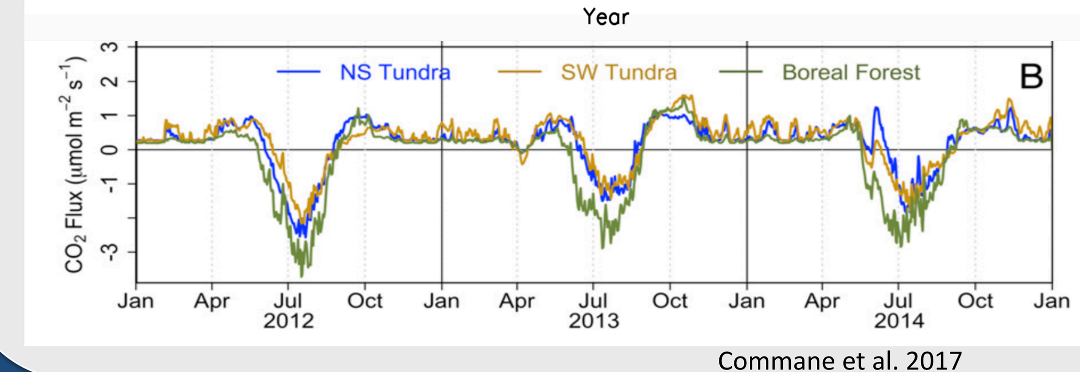


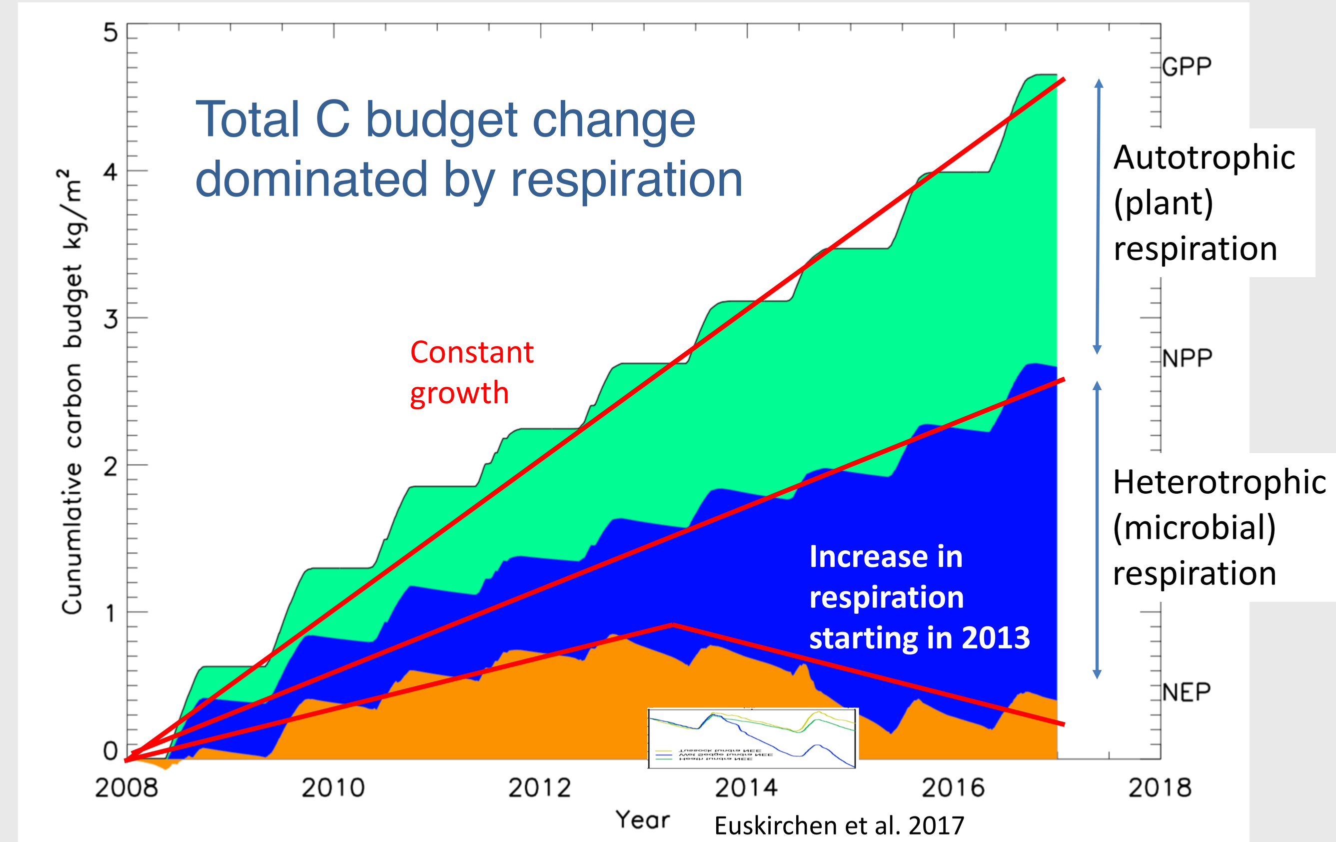
We simulate two year 2100 climates based on CMIP5 RCP8.5 models that span the range of climate change. We apply the changes in the monthly climate variables to 3 hourly tower meteorological data to create the input meteorology. The model is driven with specific humidity, precipitation, short and long wave surface radiation, and temperature.

Imnaviat Creek Carbon budget





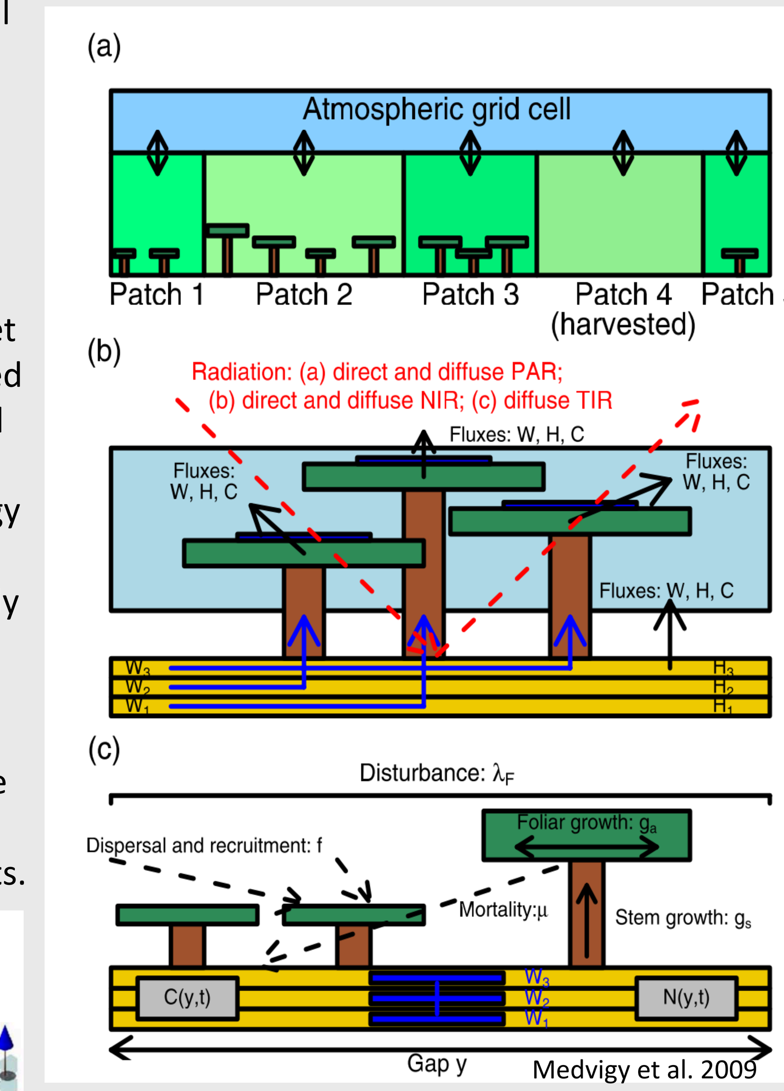


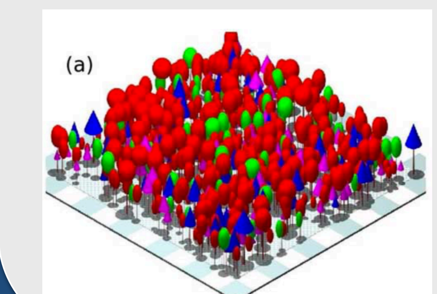


Upper left: Soil temperatures in the ED2 model along with tower observations. The model is able to accurately simulate soil temperatures and the zero curtain period, shown at left.
Lower left: Alaska CO2 fluxes over three years in three different ecosystems. Large respiration fluxes are observed in the fall/winter due to the zero curtain effect. There is also substantial interannual variability. 2013 and 2014 were warm, wet years.
Above: ED2 simulations of the carbon budget from 2008-2016 at Imnaviat Creek.

ED2 Description

- Mechanistic terrestrial biosphere model
- Conserves water, internal energy, and carbon
- Sites are driven by met data and characterized by unique geophysical morphology including soil type and hydrology
- Patches are statistically representations of ecosystems. Plants in patches interact, compete and facilitate the use of light, moisture and nutrients.



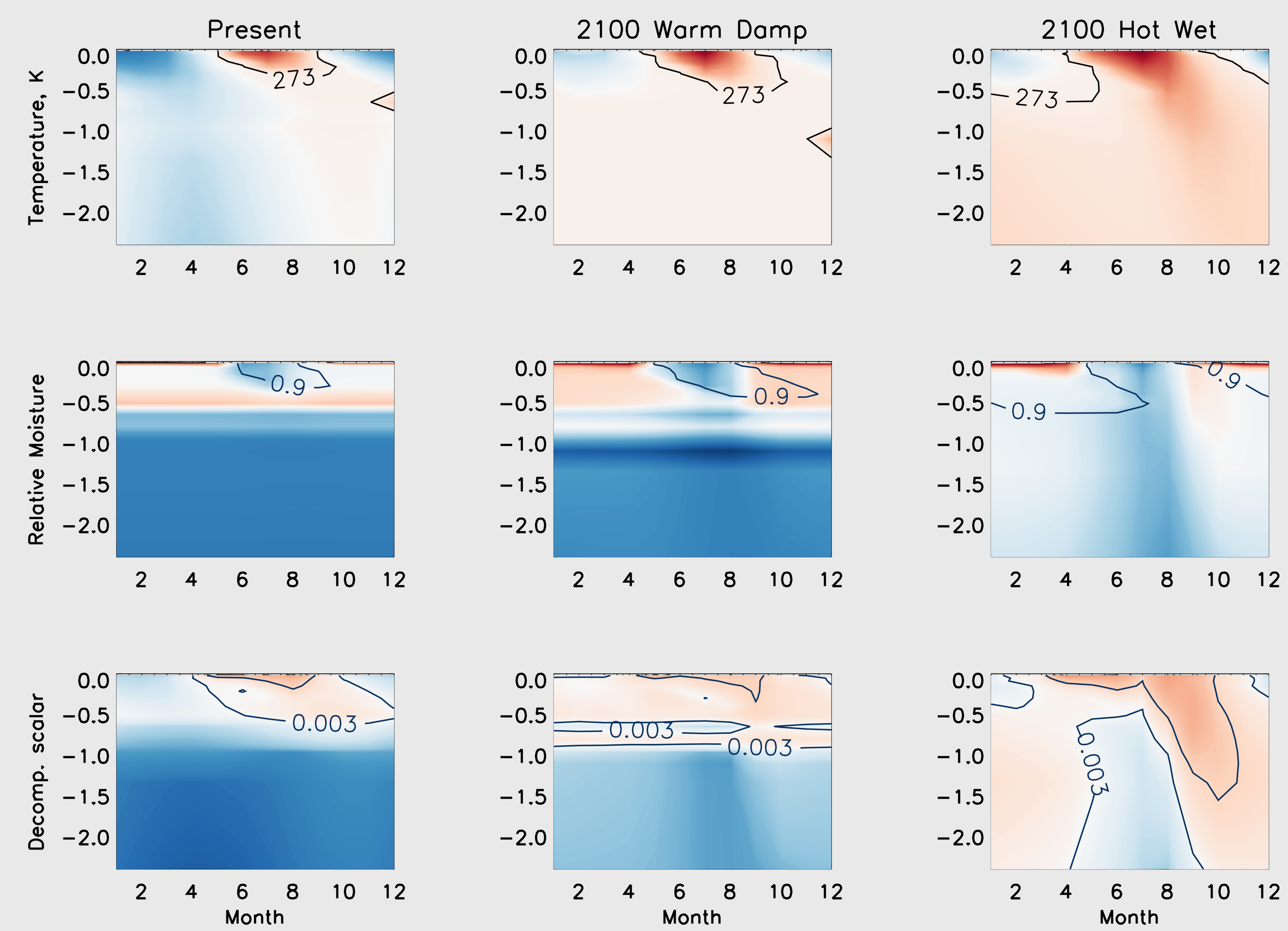


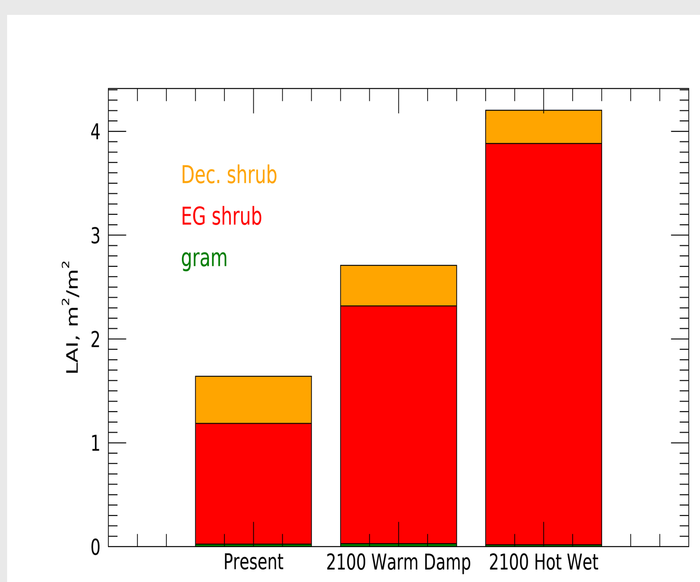
Comparing present and future climates

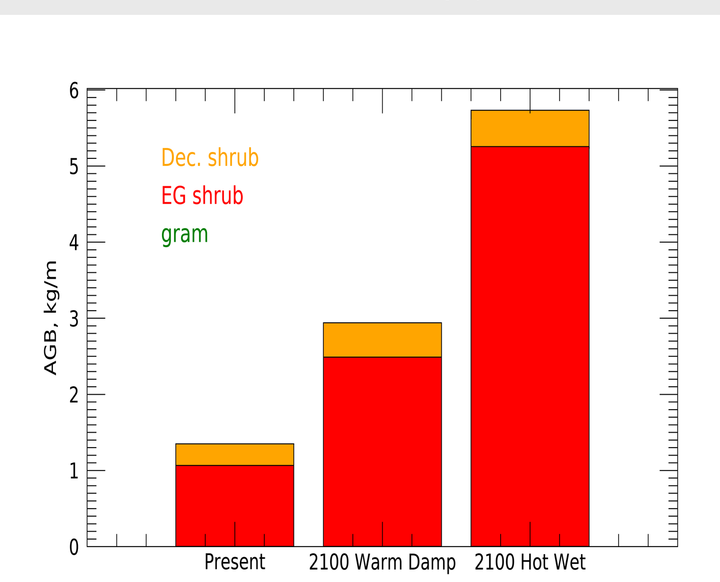
Present and future soil temperature, moisture, and respiration scalar as a function of depth and time. This is smoothed over 10 years for 3 climate scenarios, the present, 2100 "warm damp", and 2100 "warm wet". In warming climates, the whole soil column warms, and the active layer deepens. At some point between our two warming scenarios we cross a threshold where the entire soil column melts (at least down to 2.4 m).

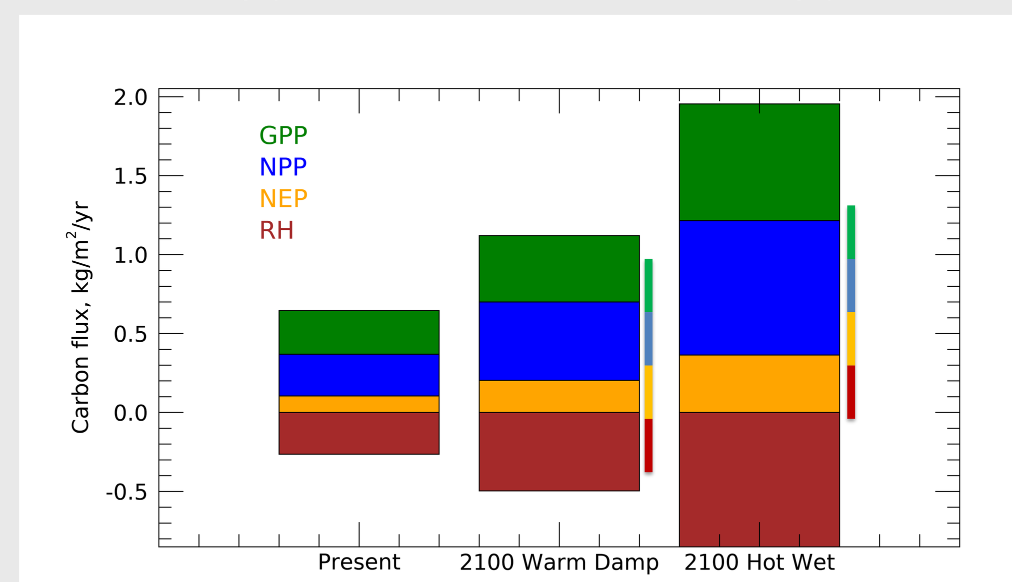
The contour in the relative soil moisture panels is the soil liquid fraction, and therefore tracks the temperature. Increased plant transpiration substantially dries the soil column in the growing season of the hot scenario, despite a 50% increase in precipitation.

Interestingly, in the warmest scenario, the respiration increases dramatically, as expected, but not in the summer. Most of the increase is in the fall/winter. This is due to increased plant transpiration drying the soil column in the growing season and decreasing the heterotrophic respiration.



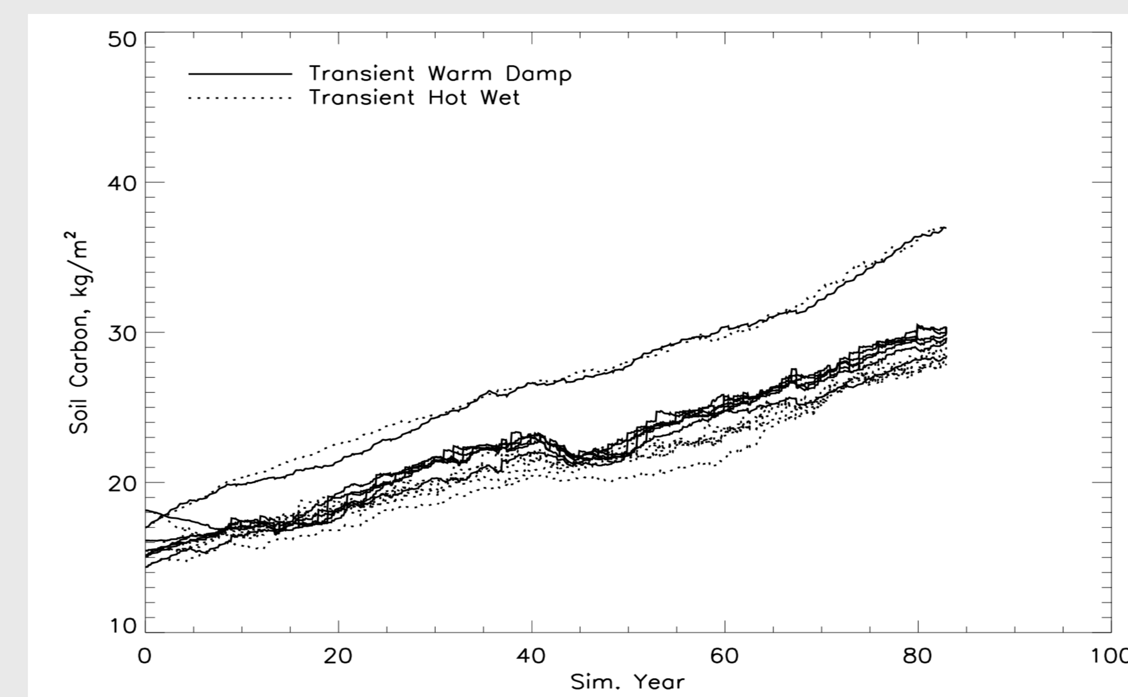






Above Left: Equilibrium LAI and AGB in present and future climates by PFT.
Above Right: Carbon fluxes in present and future climates. Year 2100 carbon fluxes are much larger and carbon is being stored in the soil.

Climate Feedback



On average, 15 kg C/m² is expected to be added to the Imnaviat Creek soil by 2100. This corresponds to a net increase in soil carbon in the Alaskan Tundra of about 2.3 Pg, with another 0.5 Pg in plant biomass. We are not seeing, by 2100 at least, a net loss of carbon from the ecosystem.

2.8 Pg of C uptake by the Alaskan Tundra ecosystem by 2100 results in a meager change in atmospheric CO_2 of -1.3 ppmv.

Over the next 100 years, the Alaskan tundra will take up roughly the equivalent of the United States anthropogenic CO_2 emissions in this year.

Acknowledgements and References

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