ABSTRACT: PROJECT OBJECTIVES: This proposal has the overall goal of producing datasets relevant for documenting changes in the global carbon cycle and improving understanding of how land ecosystems may influence and be influenced by future CO$_2$ changes and climate changes. It also has a more focused goal of using these and other data to challenge models that depict the response of changing climate and human forcing (e.g. rising CO$_2$) on northern extra-tropical ecosystems over multi-decadal time scales, using records extended over the past 50 years. Targets for model improvement include improved depiction of the response of northern extra-tropical ecosystems.

RESULTS: Observations of atmospheric CO$_2$ concentration at ground-based sites in the Northern Hemisphere show increasing trends in seasonal amplitude over the last few decades, with the largest changes at high northern latitudes. But the long-term change in CO$_2$ amplitude, and especially its spatial pattern, cannot be well-characterized using existing datasets because only Mauna Loa, Hawaii (MLO, 20°N) and Barrow, Alaska (BRW, 71°N) have records extending back to the 1950s-60s. At both of these sites, the timing of CO$_2$ drawdown has advanced by roughly one week, but the trends in amplitude differ: the amplitude at Mauna Loa increased by 15±5 % over the past 50 years while the amplitude at Barrow increased by at least twice as much.

Further insight into the amplitude changes is now possible by comparing CO$_2$ data from a recent large-scale aircraft campaign (the HIAPER Pole-to-Pole Observations or HIPPO) with observations made 50 years earlier during the International Geophysical Year (IGY). The comparison reveals, with unprecedented clarity, the magnitude and spatial pattern in long-term CO$_2$ amplitude trends and resolves a strikingly large (~50%) amplitude increase north of 45°N. The increase evidently requires an increase in summer-time NPP of order 50% focused on boreal forests, which is very difficult to explain unless major structural changes have occurred in the boreal forests the 50-year period. The trends south of 45°N are considerably smaller. The overall pattern with latitude is therefore consistent with the ground-based time series from Mauna Loa and Barrow. The Mauna Loa amplitude shows large quasi-decadal variability, which correlate well with the Pacific Decadal Oscillation (PDO) Index, probably in large part owing to changes in water status of western and middle North America that correlate with the PDO. The overall rise at Mauna Loa is not explained, however, by the PDO. The pattern revealed by the airborne and ground-based data may require both large long-term increases in NPP north of 45°N, and also small reductions in the seasonal CO$_2$ exchange at lower latitudes.