When did the Anthropocene Begin? Observations and climate model simulations.

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The accelerating industrial revolution around 1800-1850 marked a major event in the role of humans in modifying earth's climate through rising concentrations of greenhouse gases (GHGs). Ruddiman (2003) proposed that the early agricultural revolution (forest clearance, rice cultivation) caused discernible increases in GHGs beginning more than 5000 years ago. His proposal was based upon the upward trends of GHGs in the late Holocene (the last 5000 years), as measured in ice cores, compared to the downward trends of GHGs that are typical of the late stages of previous interglacials.

Ruddiman's proposal that early agriculture caused climate change has sparked additional research: analysis of GHGs in ice cores further back in time, assembly of archeological and paleoenvironmental evidence to estimate early land use changes directly, and studies with climate models to estimate what the climate might have been if late Holocene GHG concentrations had been lower (and more like the concentrations of previous late interglacials).

My talk will briefly review the above-mentioned observational studies, and then describe three climate model simulations made with the NCAR CCSM3 -- a coupled atmosphere-ocean model: the present-day climate (PD), the pre-industrial climate (PI), and a hypothetical (inferred) climate – termed Non-Anthropogenic (NA) – where NA has the low GHG levels that occurred in the late stages of previous interglacials. We find the expected trend toward colder climate (lower surface temperature, more snow and sea-ice cover, lower ocean temperature, and modified ocean circulation) as the GHG radiative forcing decreases from PD to PI to NA.

Moreover, the sensitivity of the climatic response to the change in GHG forcing becomes relatively larger for each step toward a colder climate state (the change in sensitivity from PD to PI, compared to the change from PI to NA). This increased sensitivity of climate to GHG changes for the colder climate states agrees with results of an earlier study by Manabe and Bryan who used an idealized climate model forced by a wide range of GHG concentrations. However in our study this change in sensitivity is not an idealized result, but instead helps frame important questions about possible late Holocene climate changes from NA to PI, compared to changes from PI to PD – topics that are related to Ruddiman's proposal.

The simulated climates are in the ballpark of some of the limited observations for PI and NA (inferred), and they also indicate changes in ocean CO_2 solubility, sea-ice cover, and deep ocean ventilation that may have contributed to further increases in late Holocene atmospheric CO_2 – increases beyond those attributed to early agriculture alone (positive feedbacks).