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Interannual variability and decadal trends in carbon exchange at the Harvard Forest EMS site

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The Harvard Forest EMS site in a mixed deciduous forest in central Massachusetts has been measuring carbon, water, and energy fluxes since 1992. Above-ground biomass, litter input, and tree mortality have been measured since 1995. The forest at this site has consistently been a net sink for carbon over the measurement period with annual uptake rates of 1.0 to $>$ 5.Mg-C ha^{-1}y^{-1}. Carbon uptake rates show a significant increasing trend, despite the forest being 75- 110 years old. There were parallel increases in midsummer photosynthetic capacity at high light level (21.5-31.5 μmole m^{-2}s^{-1}), woody biomass (101-115 Mg-C ha^{-1}from 1993-2005, mostly due to growth of one species, red oak), and peak leaf area index (4.5-5.5 m^{2}m^{-2}from 1998–2005). These long-term trends were interrupted in 1998 by sharp declines in photosynthetic capacity, net ecosystem exchange (NEE) of CO_2, and other parameters, followed by recovery over the next 3 years. The dip in 1998 could not be directly attributed to any one cause, though leaf expansion in the spring appeared to stall during a period of unfavorable weather, and did not recover later in the summer. Annual increment of above-ground woody biomass has followed the trend in NEE with 1 year offset implying that spring wood growth is supplied by carbon fixed in the previous year.

An empirical model of carbon fluxes based on mean temperature and light response functions and observed phenology represents the hourly to seasonal patterns in carbon fluxes but can not adequately account for interannual variability or the long-term trends in carbon uptake. A structured ecosystem model (ED2) that represented both canopy-scale physiology and long-term dynamics of tree growth, mortality, and species composition was able to simulate interannual variability over decadal intervals better than the empirical model based on mean responses could. These results imply that direct effects of climate variability only partially account for interannual variability in NEE. Other key factors appear to be indirect effects of climate forcing on leaf biomass and canopy performance, and long term successional trends in species composition and structure. Detection and attribution of the factors that control long-term trends and interannual variability requires continued long-term data records.