THE WINTER ARCTIC OSCILLATION, THE TIMING OF SPRING, AND CARBON FLUXES IN THE NORTHERN HEMISPHERE

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ABSTRACT
Increased winter temperatures associated with the observed positive trend in the winter Arctic Oscillation can partially explain trends towards earlier spring leafout in the northern hemisphere. Increased spring drawdown associated with earlier leafout, coupled with increased winter respiration due to warmer temperatures, indicate the trend in the winter Arctic Oscillation can help explain observed increases in the seasonal amplitude of atmospheric CO_2 concentration.

We hypothesize that warmer winter temperatures due to the positive trend in the winter Arctic Oscillation (AO) [*Thompson et al*., 2000] can explain observed trends towards earlier spring [*Serreze et al*., 2000] and increased seasonal amplitudes in atmospheric CO_2 [*Keeling et al*., 1995]. To test this hypothesis, we modeled leafout and terrestrial carbon fluxes using the Simple Biosphere model, Version 2 (SiB2) and the National Centers for Environmental Prediction (NCEP) reanalysis for 1958-2002.

We found positive AO polarity during winter results in positive winter temperature anomalies and earlier springs in the eastern United States and northern Europe. Our modeled leafout and associated trends were consistent with observed phenology and the winter AO trend can statistically explain 20-70% of the modeled leafout trends in the eastern United States and northern Europe [*Schaefer et al*., 2005].

Warmer winter temperatures associated with positive AO polarity in winter simultaneously increased simulated winter respiration and spring uptake of atmospheric CO_2 by plants. Positive AO polarity averaged over January-February-March (JMF) increases the surface temperatures in the southeast United States and much of Eurasia, increasing winter respiration, as indicated by positive correlations between total JFM respiration and the JFM AO index (Fig.). Positive JFM AO polarity also advances the date of leafout, resulting in a longer growing season and a greater spring drawdown, as indicated by positive correlations between total Gross Primary Productivity (GPP) from January-June and the JFM AO index (Fig. 2). Winter temperature trends resulting from a positive trend in the winter AO can thus simultaneously increase winter respiration and spring drawdown. These seasonally asymmetric trends towards increased respiration in winter and increased GPP in spring can help explain the trend towards increased seasonal amplitudes in observed atmospheric CO_2 concentration.

Our work indicates that changes in atmospheric circulation rather than direct global warming can partially explain observed trends towards earlier springs. The winter AO trend itself may result from global warming, stratospheric ozone loss, or both, but may also result from natural long-term variability in the atmosphere circulation. Also, the climate memory of terrestrial ecosystems allows the synoptic time scale variability of the winter AO to influence the timing of leafout in spring and the seasonality of terrestrial net carbon fluxes. To fully explain earlier springs, we must examine atmospheric and ecological processes at all time scales.

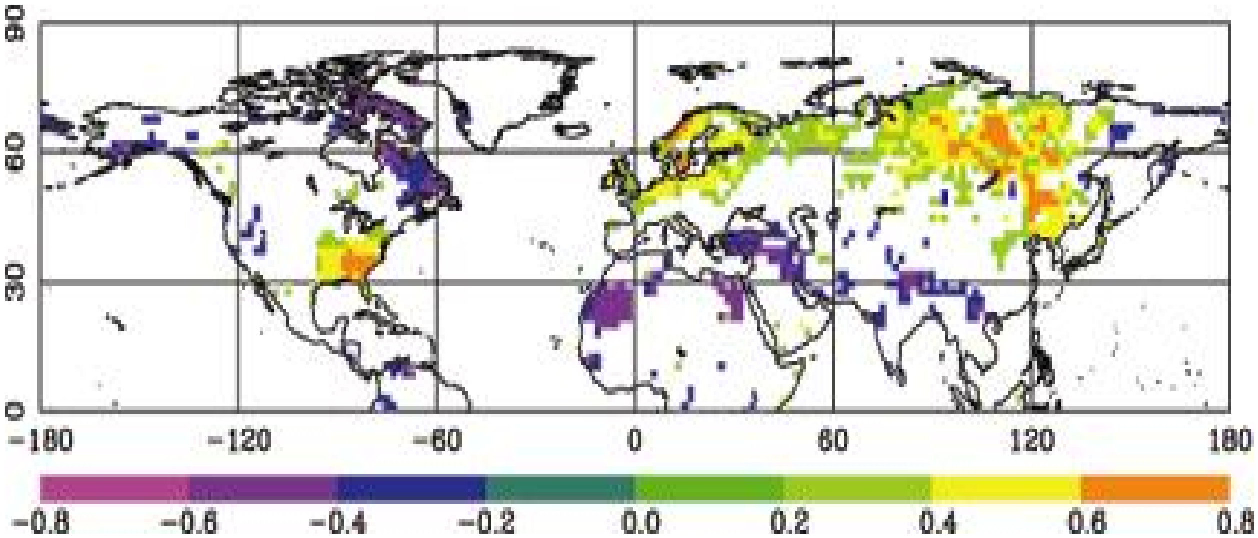

Fig. 1: Statistically significant correlations between the average JFM AO index and the simulated, total JFM respiration from 1958-2002.

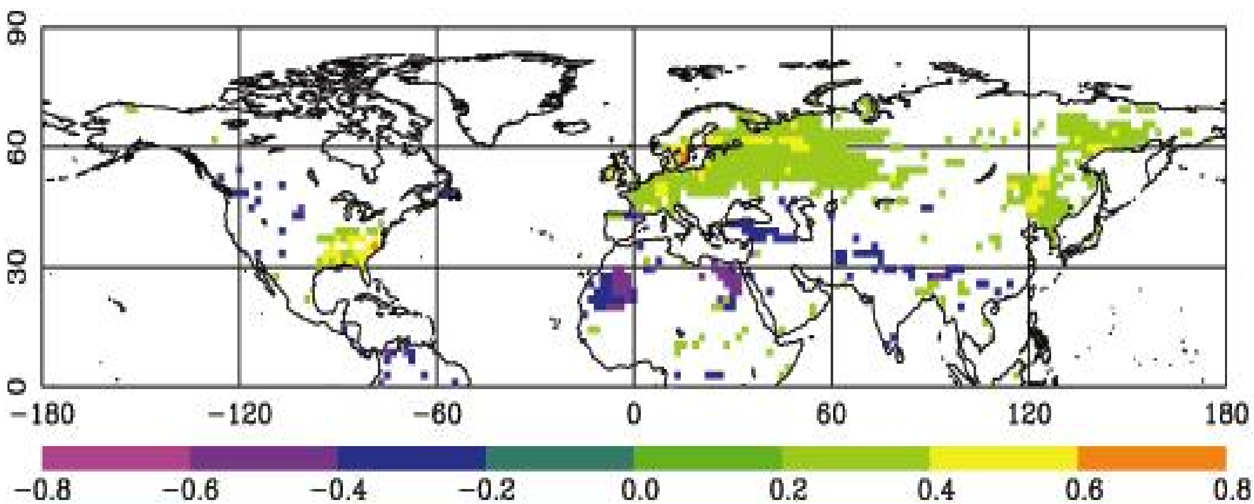

Fig. 2: Statistically significant correlations between the average JFM AO index and the simulated, total January through June GPP from 1958-2002.

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