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Climate Change at Annual Timescales

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Abstract: The annual cycle is the dominant mode of climate variability for most aspects of climate that humans engage with. Trends in the amplitude and timing of the annual cycle have been observed in both the surface temperature record and the atmospheric carbon dioxide record, but causes and significances of these changes remain poorly understood--in part because we lack an understanding of the character and mechanisms of natural variability.
Here we show that the phase of the annual cycle of surface temperature over extratropical land shifted towards earlier seasons by 1.7 days between 1954-2007, and that this change is highly anomalous with respect to earlier variations, which we take as indicative of the natural range. Significant changes in the amplitude of the annual cycle are also observed between 1954-2007. The observed land phase trends are explained by the cumulative effects of orbital changes, aliasing of the tropical year by sampling of temperature on the Gregorian calendar and changes in atmospheric circulation described by the Northern Annular Mode and the Pacific North America Pattern. These effects also appear to explain the contemporaneous amplitude gain trends, though this is less unambiguous. Ocean trends, in contrast, appear more significant after taking into account natural sources of variability.
The annual cycle of atmospheric carbon dioxide is controlled by variability in the carbon cycling of the terrestrial biosphere. Trends in the annual amplitude, timing of annual carbon draw-down (t_{drop}) and timing of annual carbon rise (t_{rise}) have thus been used to argue for a more photosynthetically active terrestrial biosphere, earlier initiation of biological spring, and increased terrestrial respiration in autumn respectively. We show that changes in amplitude are significant, anomalous when compared against a model of natural variability, spatially coherent over broad latitude bands and related to climate variability. Changes in t_{drop} are neither significant, nor anomalous, and are coherent over only limited spatial scales, indicating t_{drop} is a poor metric for diagnosing large-scale changes in the terrestrial biosphere. The utility of t_{rise} variability for diagnosing changes in the terrestrial biosphere is more ambiguous.

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