



Climate change is advancing spring onset at Acadia and across the National Park System

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Acadia National Park spring onset over the past 1-3 decades, on average, compared with the historical range of conditions (1901-2012):

- First Leaf Index: 5th percentile (earlier than 95% of historical conditions)
- First Bloom Index: 5th percentile (earlier than 95% of historical conditions)

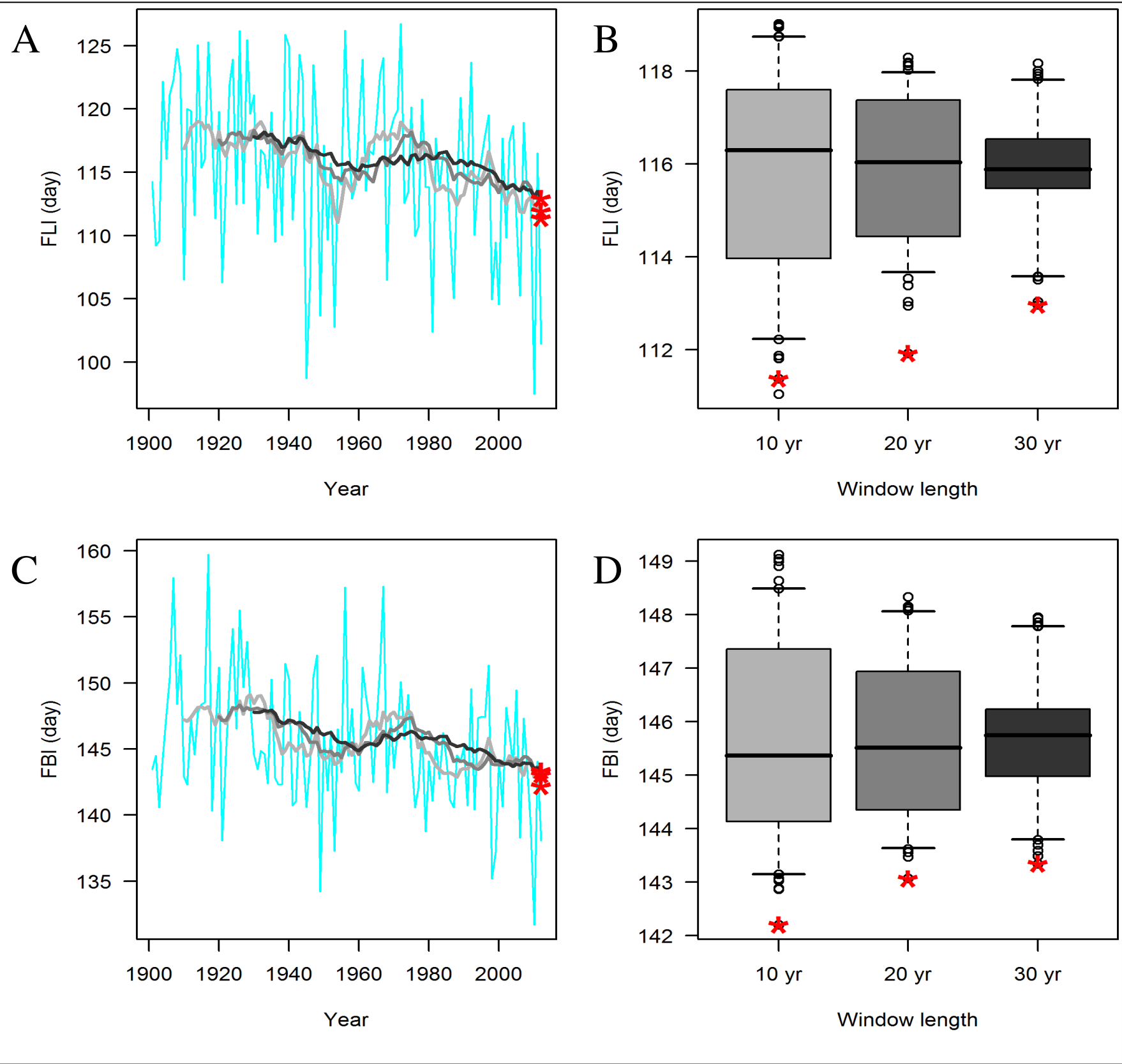


Figure 1. Acadia National Park moving window time series used to estimate historical range of variability (HRV) and recent percentiles shown for the first leaf (FLI: **A, B**) and first bloom (FBI: **C, D**). Three moving windows—10 yr (light gray), 20 yr (medium gray), and 30 yr (dark gray)—are calculated from the annual time series (blue, A and C). Values associated with each index for the most recent windows (2003–2012 [10 yr], 1993–2012 [20 yr], 1983–2012 [30 yr]) are indicated by the red asterisks. Boxes in B and D are the 25th–75th percentiles (median or 50th percentile = thick horizontal line), dashed lines the 5th to 25th and 75th–95th percentiles, and dots the outliers (<5th percentile or >95th percentile). Recent percentiles are calculated for the red asterisks, which are determined by rank-sorting the statistical distribution of FLI or FBI values within each moving window class (10, 20, and 30 yr) and then calculating the percentage of individual windows in the time series that fall below the FLI or FBI value associated with the most recent window.

Table 1. Number of parks, out of 276, that exhibited extreme early, early, average, late, or extreme late dates for start of spring, according to each of the two spring indices.

Category	First leaf index	First bloom index
Extreme early (< 5 th percentile)	82	113
Early (5 th –25 th percentile)	128	98
Average (25 th –75 th percentile)	65	54
Late (75 th –95 th percentile)	1	11
Extreme late (> 95 th percentile)	0	0

Reference:
Monahan, W. B., A. Rosemartin, K. L. Gerst, N. A. Fisichelli, T. Ault, M. D. Schwartz, J. E. Gross, and J. F. Weltzin. 2016. Climate change is advancing spring onset across the U.S. national park system. Ecosphere 00(00):e01465. 10.1002/ecs2.1465

Abstract

US national parks – from Alaska to Florida – are already experiencing climate change. Changes in phenology – the timing of seasonal biological events (e.g., leaf-out, migration, and reproduction) – constitute one of the most proximate responses to climate change. Information on phenological changes will support managers in adjusting the timing of activities, such as treating invasive species, operating visitor facilities, and scheduling seasonal events. Here, we evaluate the recent timing of spring onset (past 10-30 years) in Acadia National Park and 275 other parks relative to their historical range of conditions across the past 112 years (1901-2012). Analyses used estimates of spring onset based on predicted dates of first leaf and first bloom derived from indicator plant species and climate data. See Monahan et al. (2016) for complete results and methods.

Of the 276 parks examined, spring is advancing in three-quarters, and half are experiencing an “extreme” early spring exceeding 95% of historical conditions, as measured by first leaf index and/or first bloom index from indicator plant species (Table 1, Figures 3, 4). No parks are experiencing extreme delays in spring onset. Acadia National Park is one of the extreme early spring parks, with both first leaf and first bloom indices earlier than 95% of historical conditions (Figure 1).

Managers at Acadia and other “extreme” early parks have already been working under relatively anomalous conditions for the past 10-30 years. Our results demonstrate how changes in climate seasonality are important for understanding ecological responses, and how spatial variability in effects of climate change necessitates localized adaptation approaches.



Leaves unfurling and blossoms opening. NPS photo

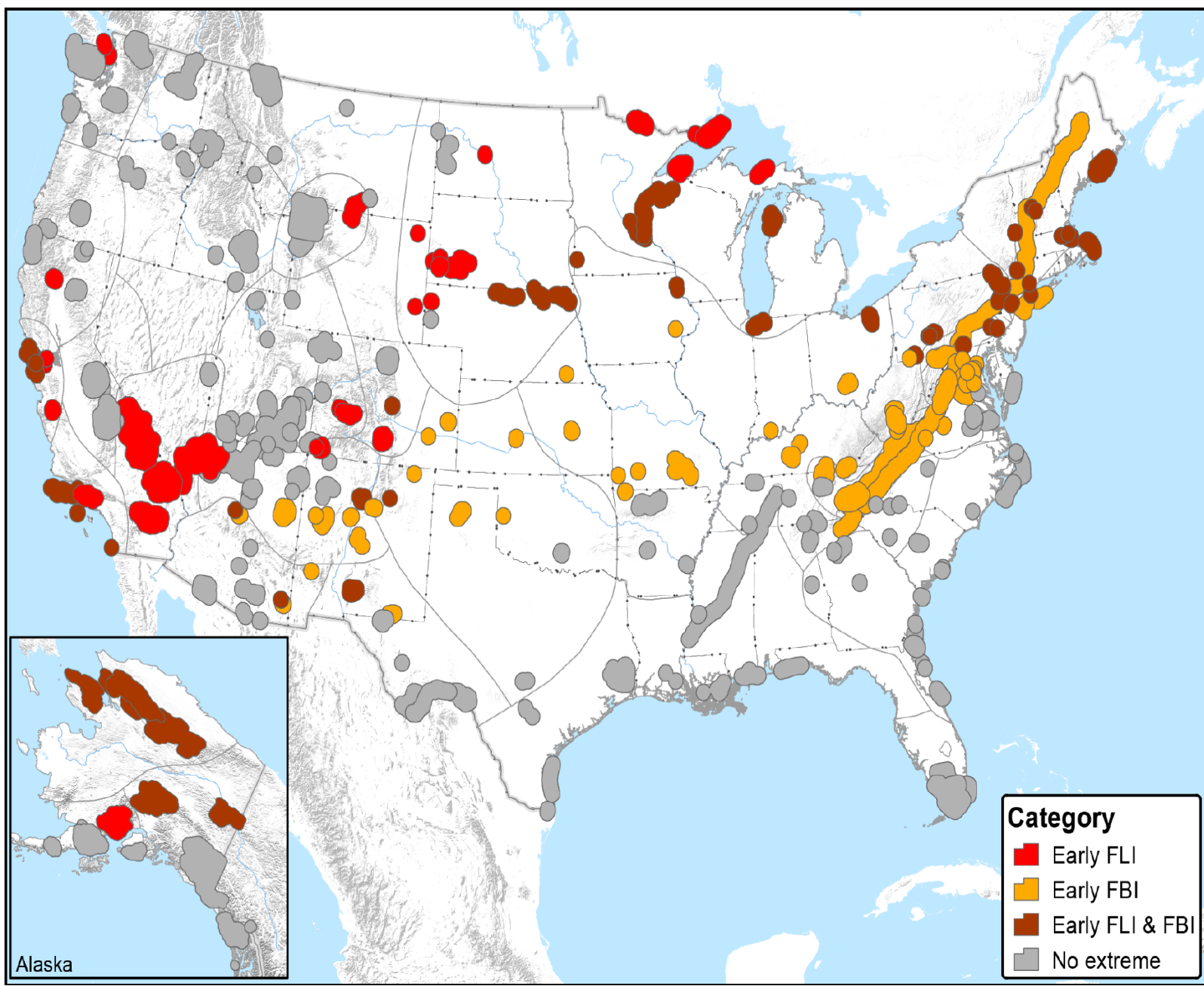


Figure 4. Categories of response to changes in the first leaf (FLI) and first bloom (FBI) indices of national parks, based on recent mean percentiles. Parks are categorized as “early” under one or both indices if the recent timing of spring onset is occurring earlier than 95% of the range of historical conditions (1901-2012).

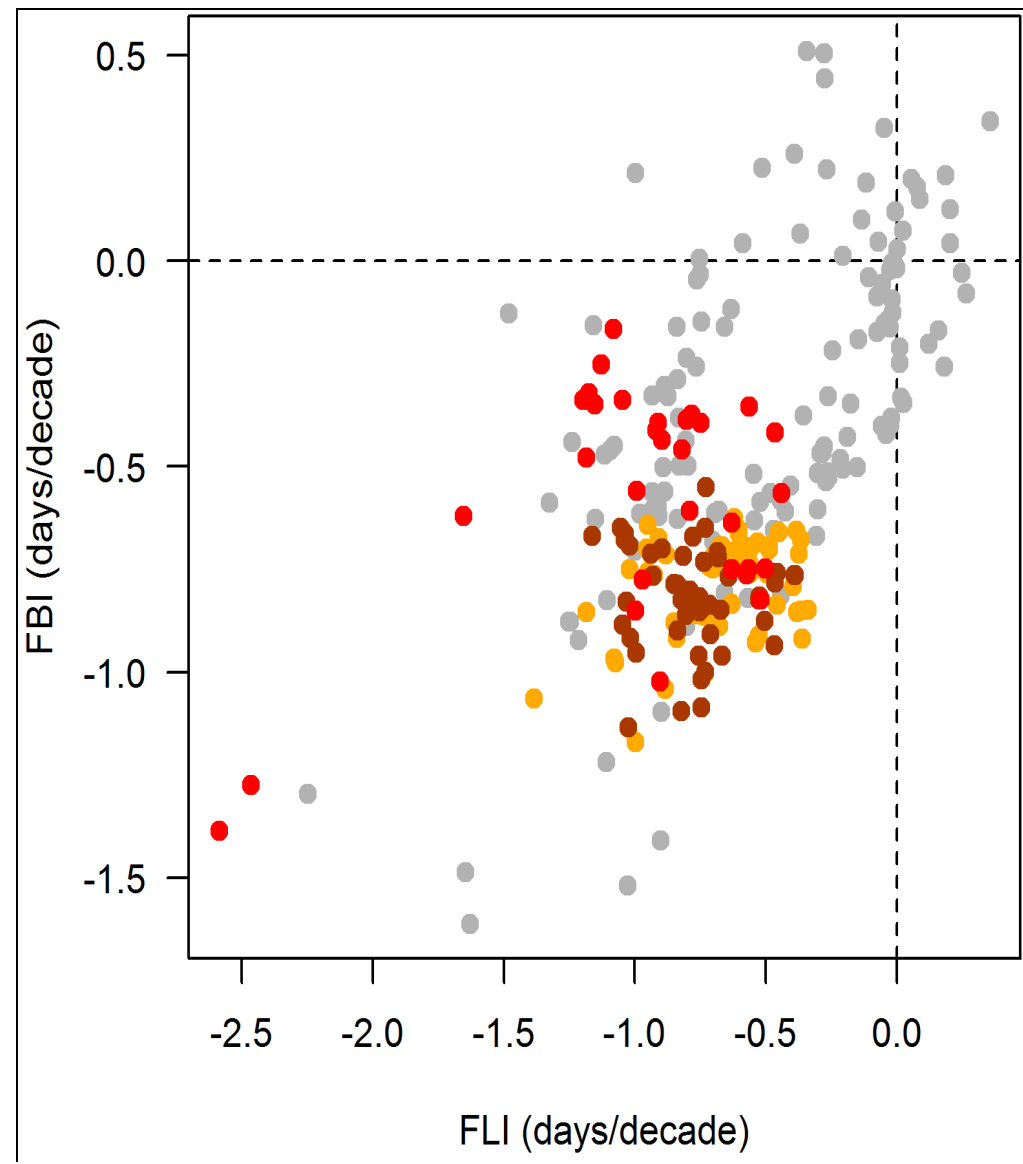


Figure 5. Recent change in the timing of spring onset, expressed in days per decade, according to the first leaf (FLI) and first bloom (FBI) indices. Colors correspond to the same ecological response categories shown in Figure 4.

The National Park Service is beginning its second century of preserving America’s natural and cultural heritage and providing for visitor enjoyment. The coming decades are likely to see continuing changes in climate and phenology. Parks will need to adapt to both the challenges and opportunities posed by these changes

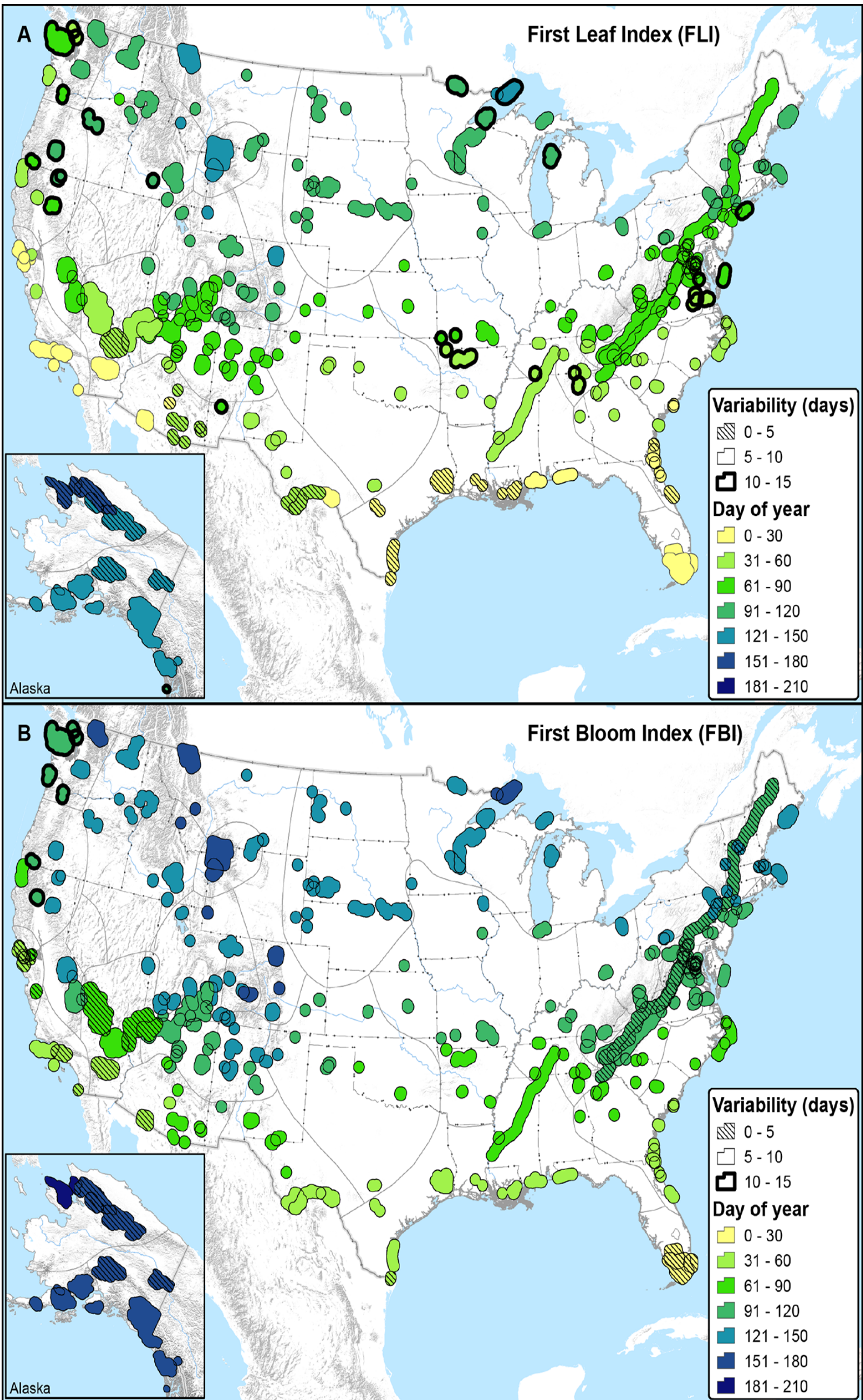


Figure 2. The recent timing of spring onset in national parks over the past 10 to 30 yr. **A)** First leaf index (FLI). **B)** First bloom index (FBI). Recent values, measured in day of the year, are calculated as the mean FLI and FBI of the most recent 10 (2003–2012)-, 20 (1993–2012)-, and 30 (1983–2012)-yr moving windows. Similarly, variability is the SD in FLI and FBI, averaged over the same time periods. In both panels, as well as in Figs. 3 and 4 (below), solid gray outlines denote NPS Inventory and Monitoring Network boundaries, which closely align with ecoregions.

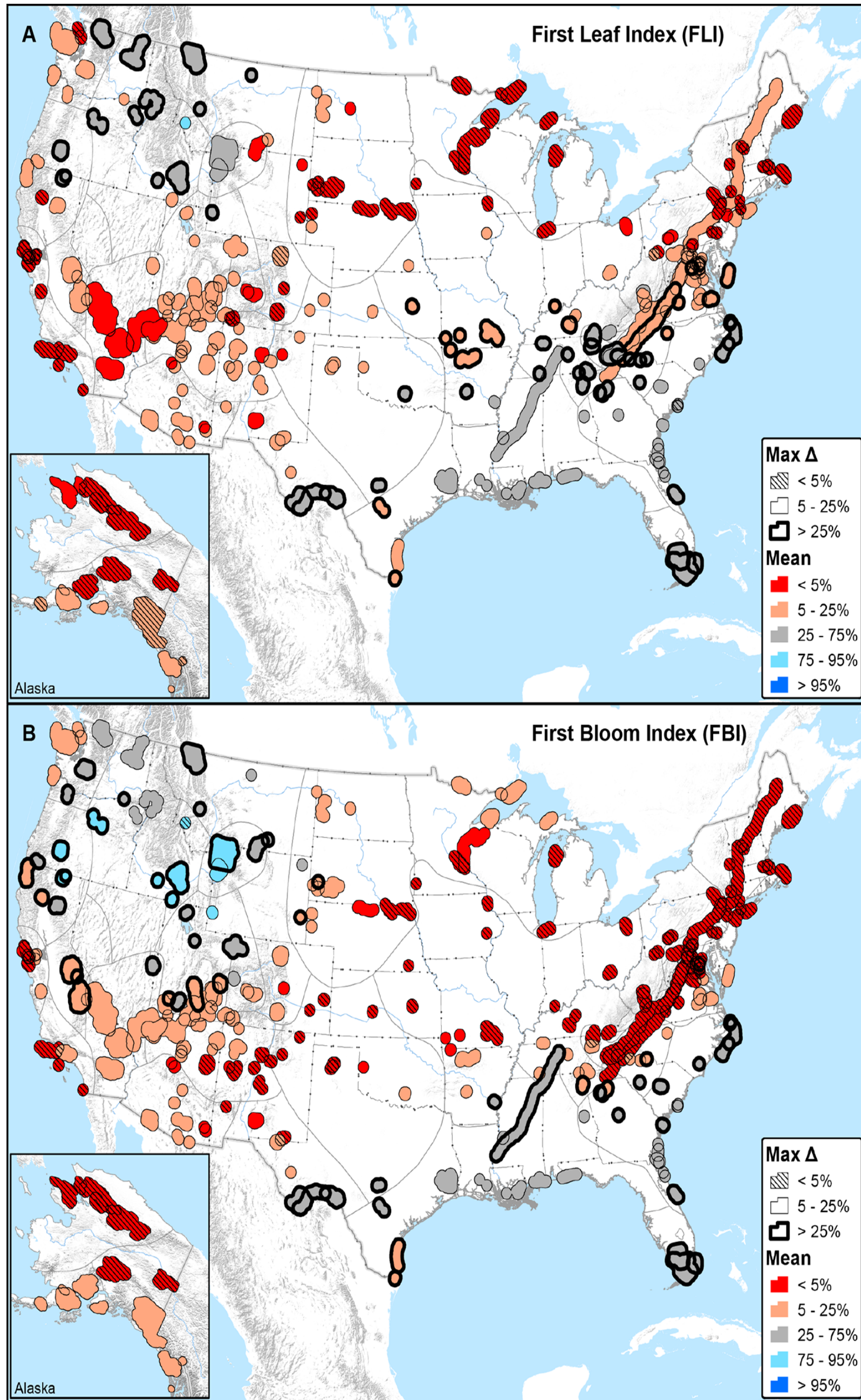


Figure 3. Recent changes in the timing of spring onset relative to the 1901–2012 historical range of variability (HRV). **A)** First leaf index (FLI). **B)** First bloom index (FBI). Mean values provide an overall measure of recent (past 10-, 20-, and 30-yr windows) change in the indices with respect to 1901–2012 HRV. Max Δ is the largest difference in percentiles among the most recent 10-, 20-, and 30-yr windows and thus measures sensitivity to moving window size (smaller values are less sensitive).

Acknowledgements
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