Differential Effects of Winter and Spring Warming on the Timing of Cherry Blossoms across a Latitudinal Gradient

Arthur Hsin-Wu Hsu, Kyungdahm Yun, and Soo-Hyung Kim
School of Environmental and Forest Sciences, University of Washington

Introduction

- Spring phenology of temperate trees is mainly determined by chilling conditions in winter for breaking dormancy and forcing conditions in spring for bud-break and flowering.
- Hypothesis: Warming in winter may extend the dormancy period leading to later bud development, while warming in spring will result in early flowering due to accelerated heat accumulation. Spring warming effect for advancing flowering time could be compensated by winter warming.

Materials and Methods

- Temperature data and Yoshino cherry (*Prunus × yedoensis*) blossom records: along a latitude gradient of locations in Japan (1952-2019) and Washington D.C. in the United States (1937-2019).
- Four contrastive winter and spring mean temperature combinations, cold winter-cold spring (CC), cold winter-warm spring (CW), warm winter-cold spring (WC) and warm winter-warm spring (WW) were classified from temperature data.
- Winter and spring warming effects were tested by advance (-) or delay (+) of bloom dates per degree changes of winter and spring mean temperature.

Results

Table 1 Average cherry blossom dates, the temperature warming effects on bloom dates (ANOVA) and spring and winter warming effects (two-way ANOVA) in four climatically contrastive years at different locations

Location	Coordinate	Climatically contrastive year (Winter-Spring)				ANOVA	Two-way ANOVA	
		Cold-Cold (CC)	Cold-Warm (CW)	Warm-Cold (WC)	Warm-Warm (WW)	p-value	Spring CW p-value	Winter CW p-value
Sapporo	43°03.6' N, 141°19.7' E	131.24 ± 0.87^{a}	125 ± 1.45^{b}	131.23 ± 1.26^{a}	124.05 ± 1.1^{b}	2.33951E-06****	2.69052E-07****	0.68244^{ns}
Aomori	40°49.3' N, 140°46.1' E	124.58 ± 0.84^{a}	116.1 ± 1.55^{b}	123.7 ± 0.82^{a}	115.43 ± 0.86^{b}	6.26915E-11****	1.21577E-10****	0.47937^{ns}
Washington DC	38°52.9' N, 77°02.5' W	96.5 ± 1.09^{a}	90 ± 1.35^{b}	97.9 ± 1.13^{a}	88.7 ± 1.38^{b}	3.78474E-07****	2.18703E-08****	0.95965^{ns}
Sendai	38°15.7' N, 140°53.8' E	110.54 ± 0.88^{a}	102.6 ± 1.5^{b}	109.5 ± 0.99^{a}	102.39 ± 0.79^{b}	1.77565E-09****	2.32166E-09****	0.56502^{ns}
Tokyo	35°41.5' N, 139°45.0' E	96.62 ± 0.87^{a}	89 ± 1.84^{b}	97.75 ± 1.16^{a}	91.6 ± 0.93^{b}	1.20048E-05****	1.43433E-06****	0.15348^{ns}
Yokohama	35°26.3' N, 139°39.1' E	96.6 ± 0.74^{a}	89.11 ± 1.39^{b}	98.22 ± 1.4^{a}	92.04 ± 0.87^{b}	1.09439E-06****	6.26321E-08****	0.04523*
Kyoto	35°00.8' N, 135°43.9' E	98.42 ± 0.78^{a}	93.7 ± 1.29^{b}	99.3 ± 0.92^{a}	94.13 ± 0.69^{b}	2.40356E-05****	2.59842E-06****	0.49478^{ns}
Tokushima	34°04.0' N, 134°34.4' E	96.26 ± 0.71^{ab}	91.55 ± 1.13^{c}	98.27 ± 0.74^{a}	95.23 ± 0.57^{b}	3.13557E-05****	9.69971E-06****	0.00078***
Fukuoka	33°34.9' N, 130°22.5' E	94.52 ± 0.79^{a}	89.91 ± 1.53^{b}	96.55 ± 0.58^{a}	90.23 ± 0.75^{b}	6.26035E-06****	4.15588E-07****	0.23069^{ns}
Kochi	33°34.0' N, 133°32.9' E	91.5 ± 0.8^{a}	84.83 ± 1.01^{c}	94.25 ± 1.07^{a}	89.14 ± 0.92^{b}	6.79547E-07****	1.11633E-07****	0.00065***
Oita	33°14.1' N, 131°37.1' E	96.13 ± 0.84^{ab}	90.91 ± 0.86^{c}	97.19 ± 0.83^{a}	94 ± 0.9^{b}	0.00056***	6.28291E-05****	0.038456*
Miyazaki	31°56.3' N, 131°24.8' E	92.68 ± 0.76^{b}	88.17 ± 1.14^{c}	96.33 ± 0.97^{a}	92.57 ± 0.63^{b}	3.75722E-06****	1.1038E-05****	1.75196E-05****
Kagoshima	31°33.3' N, 130°32.8' E	93.36 ± 0.78^{b}	89.92 ± 0.94^{c}	97.92 ± 0.9^{a}	94.24 ± 0.88^{b}	1.81873E-05****	2.7E-04***	9.89154E-06****

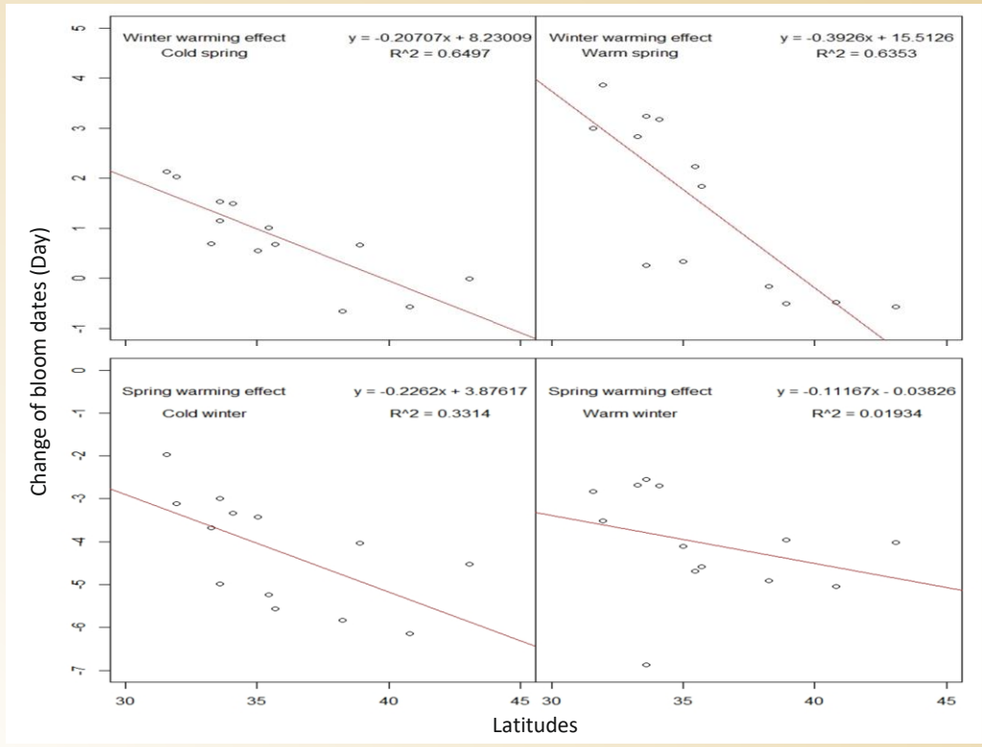

Fig. 1 Winter warming effects followed by cold (top left) and warm (top right) spring, spring warming effects after cold (bottom left) and warm winter (bottom right) along the latitude gradient. Positive change of bloom dates means delay and negative means advance.

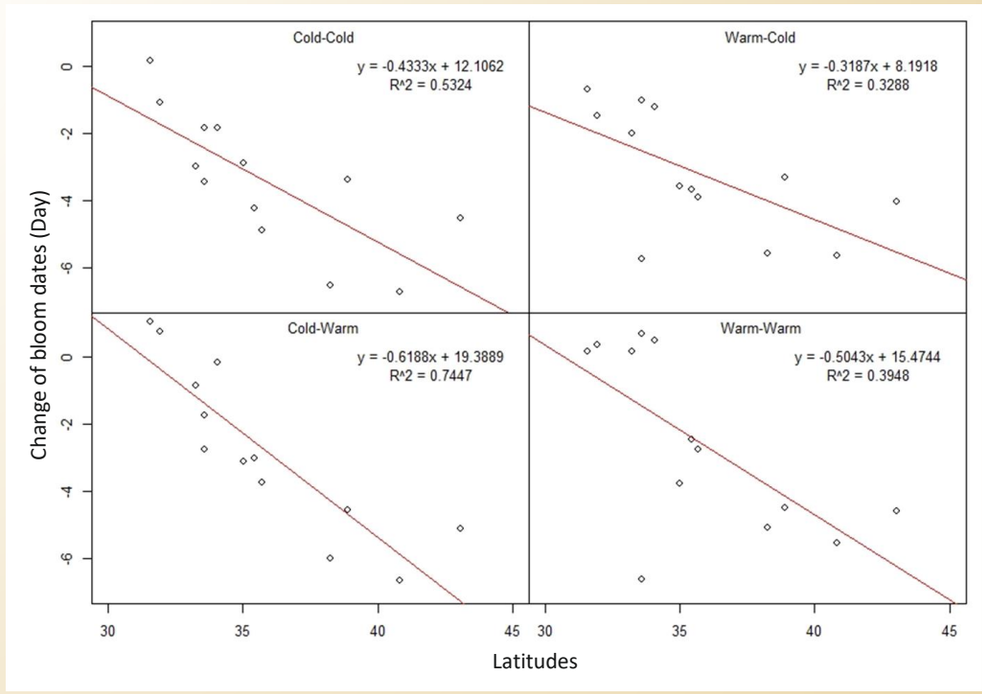

Fig. 2 Net (winter + spring) warming effects in four climatically contrastive years along the latitude gradient. Positive change of bloom dates means delay and negative means advance.

Conclusions

- Warmer spring temperatures advance flowering at all latitudes.
- Warmer winter temperatures have significant effect at lower latitudes, but no effect at high latitudes
- The effect of spring warming is stronger than winter warming.
- Spring warming effect for advancing flowering time could be compensated by winter warming.
- Winter and spring warming have differential effects on the timing of cherry blossoms across a latitudinal gradient.

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