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The first-flowering dates for the major fruit trees in Korea projected by multi-RCM ensemble

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1. Introduction

- As phenology reacts sensitively to variations of climatological environment, it is important in both economy and ecology because it is associated with harvest, nutrient cycling and cultural activities. Furthermore, phenology plays a key role in controlling the climate system through vegetation feedbacks associated with albedo, surface roughness length, canopy conductance and fluxes of water and energy. Therefore, it is crucial to understand how individual plant species in diverse regions may respond to global warming on the basis of phenology.
- We examine future possible change on the first-flowering date (FFD) under global warming using the national standard scenarios, which ultimately explore the feasibility of regional climate simulations on the agricultural sector. Therefore, the aim of the specific study is to investigate possible changes in the future FFD of three deciduous trees (cherry, peach and pear) under multi-RCP scenarios (RCP2.6, 4.5, 6.0 and 8.5).

2. Data and Method

Regional climate datasets

- **The Korean national downscaling project (Korean Meteorological Administration, 2015)**

Model acronym	WRFv3.4	RegCM4	GRIMs	SNURCM	HadGEM3-RA
Horizontal resolution	12.5km(180×201)	12.5km (180×200)	12.5km (180×201)	12.5km (180×200)	12.5km (180×200)
Vertical resolution	Eta-28	Σ-23	Σ-28	Σ-24	Hybrid-38
Dynamic framework	Non-hydrostatic	Hydrostatic	Hydrostatic	Non-hydrostatic	Non-hydrostatic
PBL scheme	YSU	Holtslag	YSU + stable BL	YSU	Nonlocal scheme
Convective scheme	Kain-Fritsch	MIT-Emanuel	SAS + CMT	Kain-Fritsch II	Revised mass flux
Land surface	Noah	CLM3.5	OML climatology	CLM3.0	MOSES-II
Long/Shortwave radiation scheme	CAM	CCM3	GSFC	CCM2	Generalized 2-stream
Spectral nudging	No	Yes	Yes	Yes	No

The First-Flowering Date(FFD) datasets

- **Trees: Cherry, peach, pear**
- **Phenological model: DTS**(the number of Days Transformed to Standard temperature) **model (Ono and Konno, 1999)**

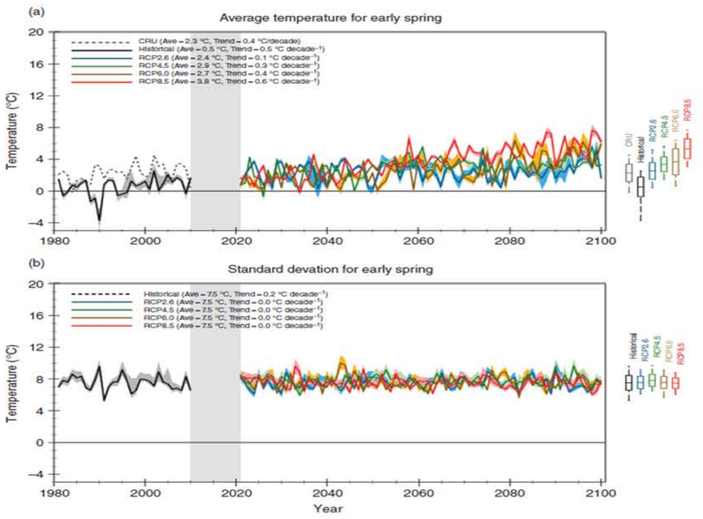
$$\sum_{i=Ds}^{nday} (\text{daily DTS})_{ij} = \sum_{i=Ds}^{nday} \left\{ \exp\left[Ea\left(T_{ij} - T_s\right) / R \cdot T_{ij} \cdot T_s \right] \right\}$$

[Cherry] *Ds*: 37, *Ea*: 64, DTS: 134
[Peach] *Ds* : 34, *Ea*: 72, DTS: 170
[Pear] *Ds*: 44, *Ea*: 64, DTS: 152

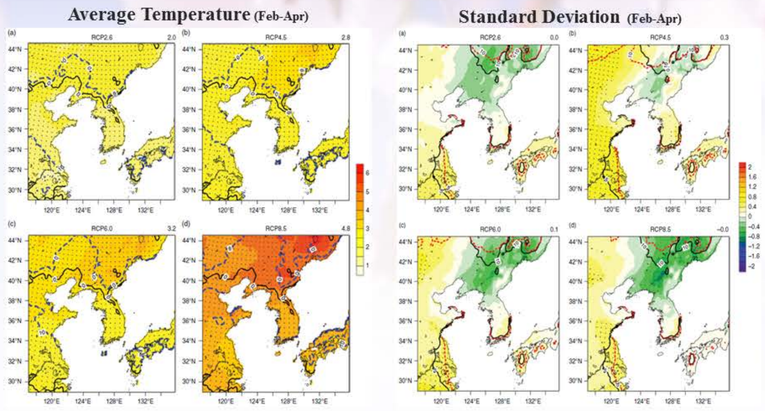
Tij : daily mean temperature ; Ts: standard temperature (271.4K) ; R: universal gas constant (8.314 JK^{-1} mol $^{-1}$); Ea: sensitivity of plants to temperature ($KJmol^{-1}$); Ds, starting day of calculation (day of year, DOY).

3. Result and Discussions

Changes in the daily mean temperature under the four RCP scenarios

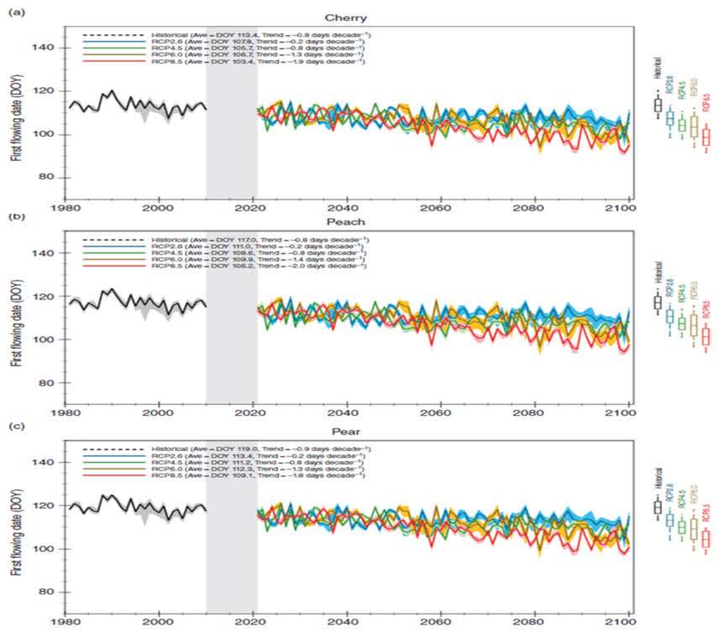


- The warming trend for 2021–2100 over north-eastern Asia is 0.1℃/decade for RCP2.6, 0.3℃/decade for RCP4.5, 0.4℃/decade for RCP6.0 and 0.6℃/decade for RCP8.5. Future standard deviation projected under RCP scenarios is expected to remain at the present level of 7.5℃, indicating that the degree of alternation in daily fluctuation is not proportional to the increase of radiative forcing.



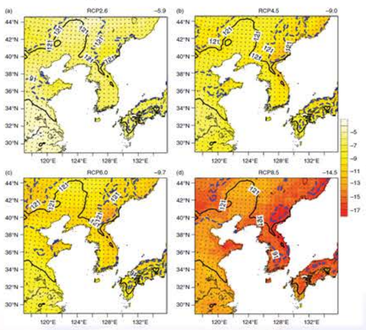
- The temperature increment is relatively greater at highlands and high latitude than in low-lying areas and low latitude. The 0 and 10℃ lines located around 40º and 29ºN in the Historical simulation are moved poleward by about 3º and 10ºN by 2100 to around 43◦ and 39◦N, respectively, under RCP8.5 scenarios at 120ºE.
- The daily variation is decreased in the region (123º~132ºE, 38º~44ºN) where temperature rise is more pronounced, while that over the other areas is increased.

Changes in the FFD under the four RCP scenarios



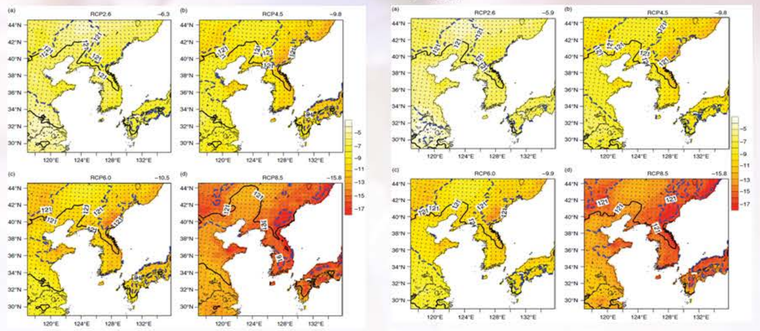
- FFD is gradually advanced for 2021–2100, while early spring mean temperature continues to rise under global warming. The average yearly advances of cherry FFD are 0.2, 0.8, 1.3, 1.9 days/decade in the RCP2.6, 4.5, 6.0, 8.5 simulations, respectively. The advancing tendencies for peach (0.2, 0.8, 1.4, 2.0 days/decade) and pear (0.2, 0.8, 1.3, 1.8 days/decade) are similar with that of cherry over all scenarios.

Cherry

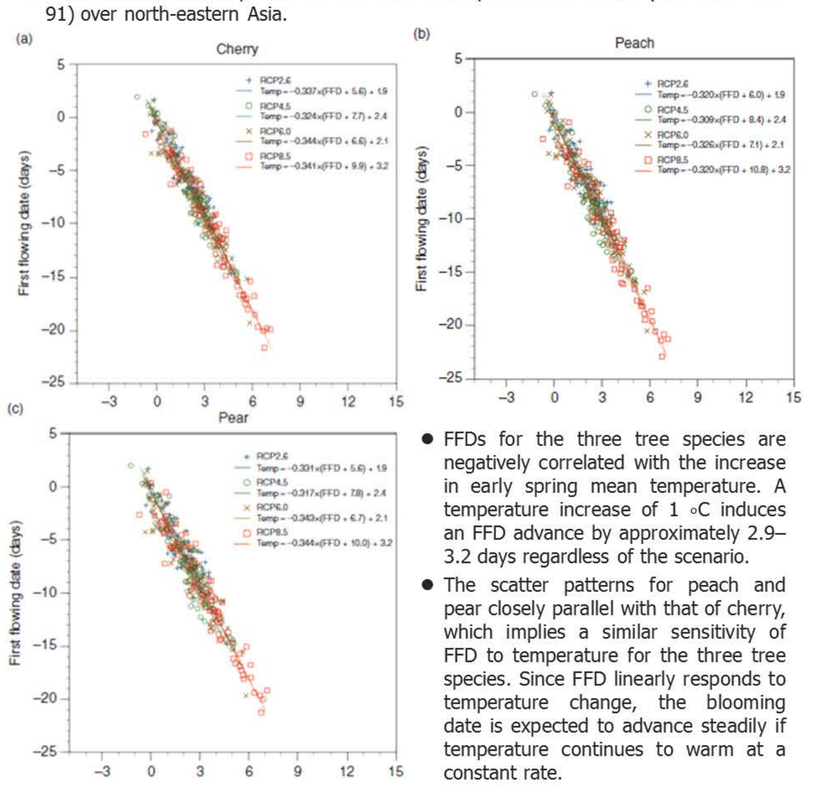


- FFDs from the Historical simulation (black solid line) are earlier at low latitude and low-lying areas than at high latitude and highlands due to the topographical effect. The four RCP simulations show advancement of FFD for the three tree species over the analysis domain while maintaining the topographic effect.
- In the cherry FFD distribution, the DOY 91 line, not shown in the Historical and RCP 2.6 simulations, appears in South Korea under RCP 4.5, 6.0 and 8.5 scenarios due to temperature warming. This indicates that cherry trees are expected to flower in March over the southern part of the Korean Peninsula.

Peach **Pear**



- Peach FFD in South Korea is also expected to start flowering in late March under RCP 8.5 scenario, which is 15.8 days earlier than the present average.
- The mean advancement of pear FFD is in range of 5.9–14.5 days and greater in highlands and at high emission scenario.
- The advancement of FFD is greater in highlands compared with that at low altitude, which reflects the temperature variation pattern.
- More blossoms are expected for the three tree species from March (less than DOY 91) over north-eastern Asia.



- FFDs for the three tree species are negatively correlated with the increase in early spring mean temperature. A temperature increase of 1 ◦C induces an FFD advance by approximately 2.9–3.2 days regardless of the scenario.
- The scatter patterns for peach and pear closely parallel with that of cherry, which implies a similar sensitivity of FFD to temperature for the three tree species. Since FFD linearly responds to temperature change, the blooming date is expected to advance steadily if temperature continues to warm at a constant rate.

4. Concluding remarks

- Validations and feasible changes of both early spring temperature and FFD were investigated using 20th century simulation (1981–2010) and 21st century projection (2021–2100) produced by the Korean national downscaling project.
- On the basis of projections, the early spring temperatures over north-eastern Asia under the RCP2.6, 4.5, 6.0 and 8.5 scenarios were expected to increase by about 2.0, 2.8, 3.2 and 4.8 ◦C, respectively, at the end of this century.
- These increments tend to accelerate blooming rate, thereby advancing the FFDs of cherry, peach and pear by about 14.5, 15.8 and 14.5 days by 2100 under the highest emission scenario, respectively. However, if the greenhouse gas emission mitigation policy that limit temperature rise to 2 ◦C (RCP2.6) is achieved, the FFD change will be reduced by about 8.6–9.5 days at the end of the 21st century compared with RCP8.5.

Acknowledgements

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Reference

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