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Urban warming advances spring phenology but reduces the response of phenology to temperature in the conterminous United States

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Outline

Background

Methods

Result and Discussion

Background

Phenology

A branch of science dealing with the relations between climate and periodic biological phenomena (such as plant flowering)

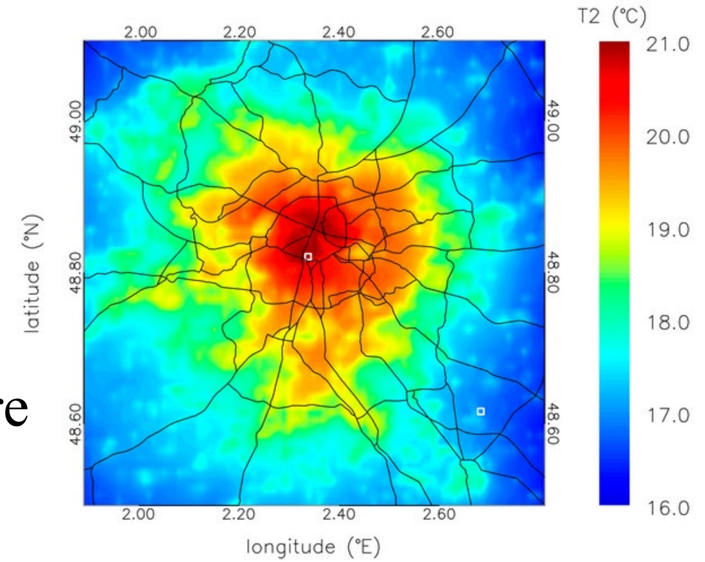
The timing of recurring events in a plant is sensitive to biotic and abiotic environmental variations 's life cycle.

Urbanization

It transformed environmental conditions of urban terrestrial ecosystems.

A well-known phenomenon associated with urbanization is the UHI.

Cities can serve as natural laboratories for examining the effects of future warming conditions on ecosystems.



Previous studies and Research design

Previous studies

- Numerous studies have observed earlier flowering in urban than in rural areas. US, EU,CHN.
- However, these studies did not capture the interurban variation in phenological change.
- Recent studies reported between land surface temperature[LST] and phenology.
- But LST could cause large biases in quantifying the temperature response of phenology.

How and why

-How and why the phenology to temperature differs in urban and rural areas remain largely unexplored.

Background

Three question

Focus on:

- How have phenology changed in large US cities?
- Were these phenological changer and their magnitudes influenced by background climatic conditions and the modified local environments(UHI)?
- What physiological mechanisms drove these phenological changes?

Outline

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Methods

The urban extent data

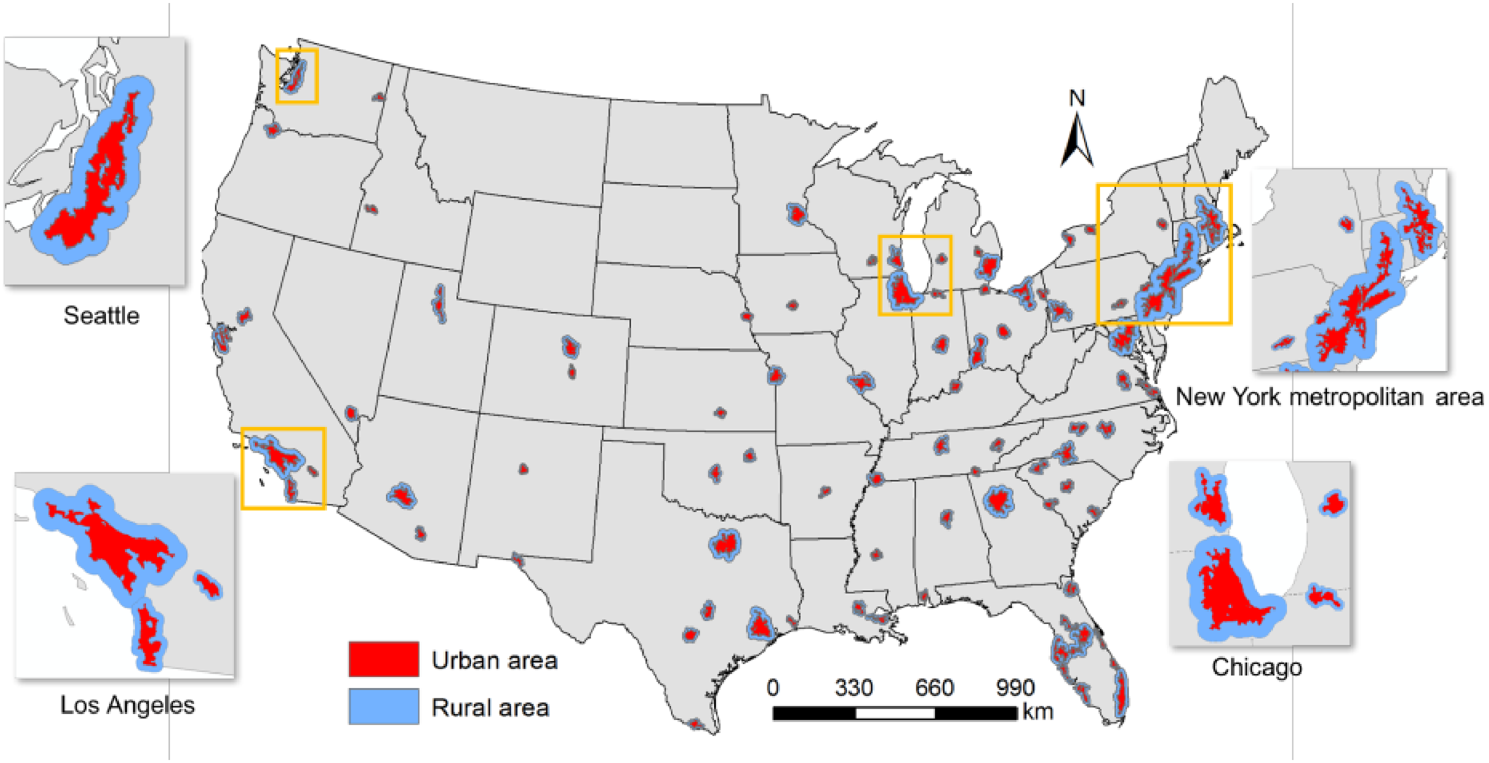


Fig. S1. Urban and rural boundaries of 85 study cities

The National Land Cover Database 2011 was used to classify pixels of urban (30 x 30m)

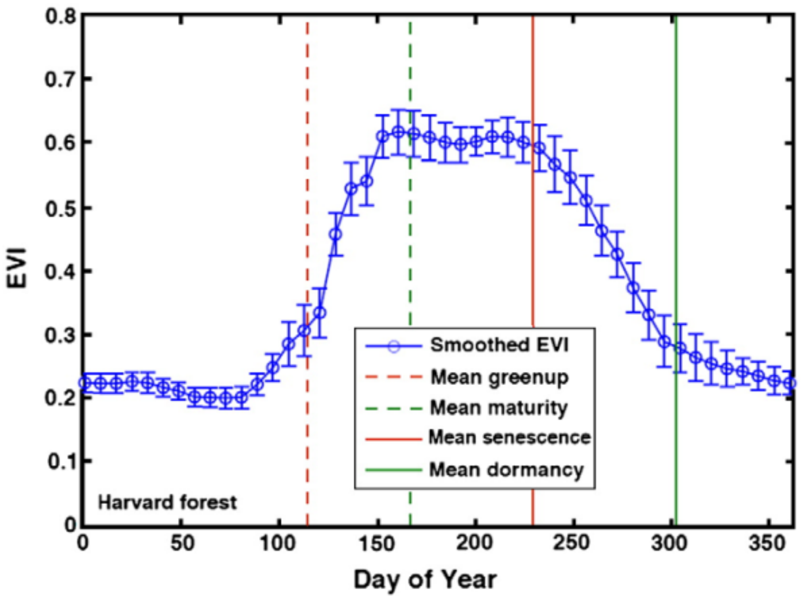
The urban extent was derived from the Defense Meteorological Satellite nighttime light data (500 km^2)

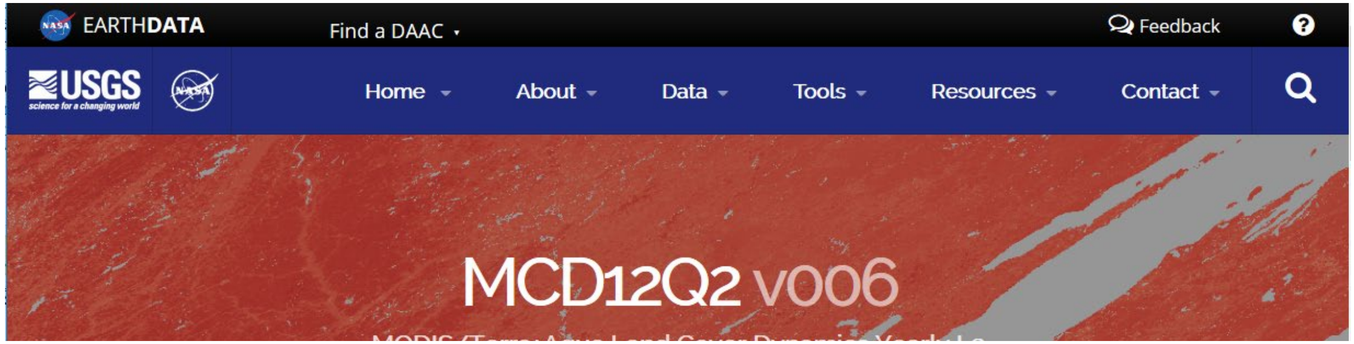
Rural areas with the same area as the inner city are used as buffer zones.

Methods

Start of Season **(SOS)**

- MODIS Land Cover Dynamics (MCD12Q2)
- The period 2001-2014.





SDS Name	Description	Units	Data Type	Fill Value	No Data Value	Valid Range	Scale Factor
NumCycles	Total number of valid vegetation cycles with peak in product year	Number	16-bit signed integer	32767	N/A	0 to 7	N/A
Greenup¹	Date when EVI2 first crossed 15% of the segment EVI2 amplitude	Day	16-bit signed integer	32767	N/A	11138 to 32766	N/A
MidGreenup¹	Date when EVI2 first crossed 50% of the segment EVI2 amplitude	Day	16-bit signed integer	32767	N/A	11138 to 32766	N/A
Peak¹	Date when EVI2 reached the segment maximum	Day	16-bit signed integer	32767	N/A	11138 to 32766	N/A
Maturity¹	Date when EVI2 first crossed 90% of the segment EVI2 amplitude	Day	16-bit signed integer	32767	N/A	11138 to 32766	N/A
MidGreendown¹	Date when EVI2 last crossed 50% of the segment EVI2	Day	16-bit signed	32767	N/A	11138 to	N/A

Methods

How and why

R_T

R_T:

partial correlation coefficient between **SOS vs Preseason mean air temperature**

R_T情况	物理解释	相关程度
R_T负	SOS是随季前均温升高而提前	
R_T大(绝对)		因季前均温升高而SOS提前的相关度越大
R_T小(绝对)		因季前均温升高而SOS提前的相关度越小

- TopoWx dataset : monthly air temperature
- Daymet datasets: monthly precipitation and shortwave radiation. 1x1km grid data

Methods

Phenology models

Alternating (ALT)

$$R_f(t) = \begin{cases} x(t) - T_{\text{base}} & x(t) > T_{\text{base}} \\ 0 & x(t) \le T_{\text{base}} \end{cases}$$

$$S_f(t) = \sum_{t_0} R_f(x(t))$$

$$R_c(t) = \begin{cases} 1 & x(t) < T_{\text{base}} \\ 0 & x(t) \ge T_{\text{base}} \end{cases}$$

$$S_c(t) = \sum_{t_0} S_c(x(t))$$

Parallel (PAR)

$$R_f(t) = \begin{cases} \dfrac{28.4}{1 + \exp(3.4 - 0.185 * x(t))} & x(t) > 0 \\ 0 & x(t) \le 0 \end{cases}$$

$$S_f(t) = \sum_{t_0} R_f(x(t))$$

$$R_c(t) = \begin{cases} 0 & x(t) \ge 10.4 \text{ or } x(t) \le -3.4 \\ \dfrac{x(t) + 3.4}{T_{\text{opt}} + 3.4} & -3.4 < x(t) \le T_{\text{opt}} \\ \dfrac{x(t) - 10.4}{T_{\text{opt}} - 10.4} & T_{\text{opt}} < x(t) < 10.4 \end{cases}$$

$$S_c(t) = \sum_{t_0} S_c(x(t))$$

Phenology metric is predicted to occur when $S_f(t) \ge a + b * \exp(c * S_c(t))$.

Where T_{base} is the base temperature for forcing and chilling and where a, b, c ($c < 0$), and t_0 are parameters need to be calibrated.

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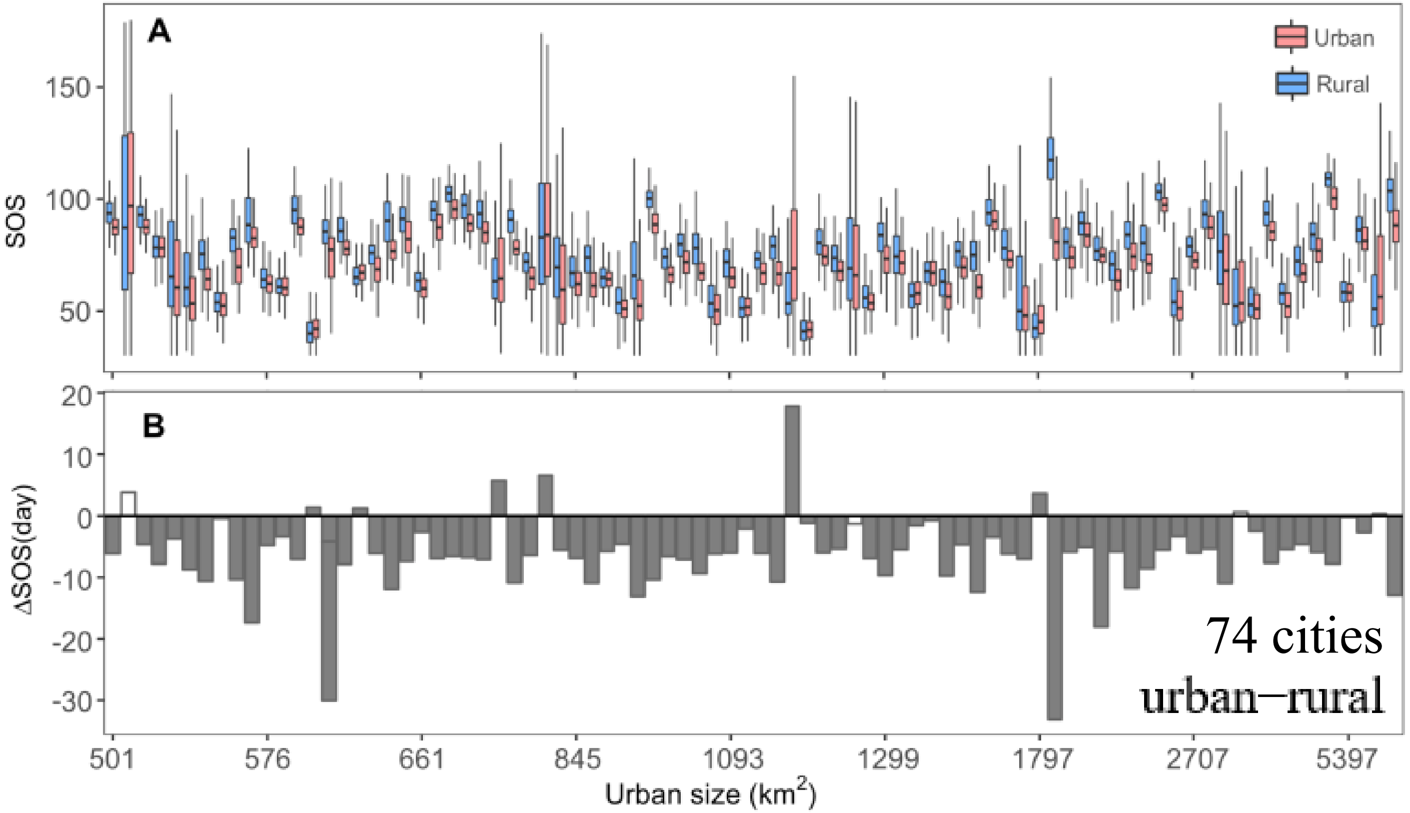
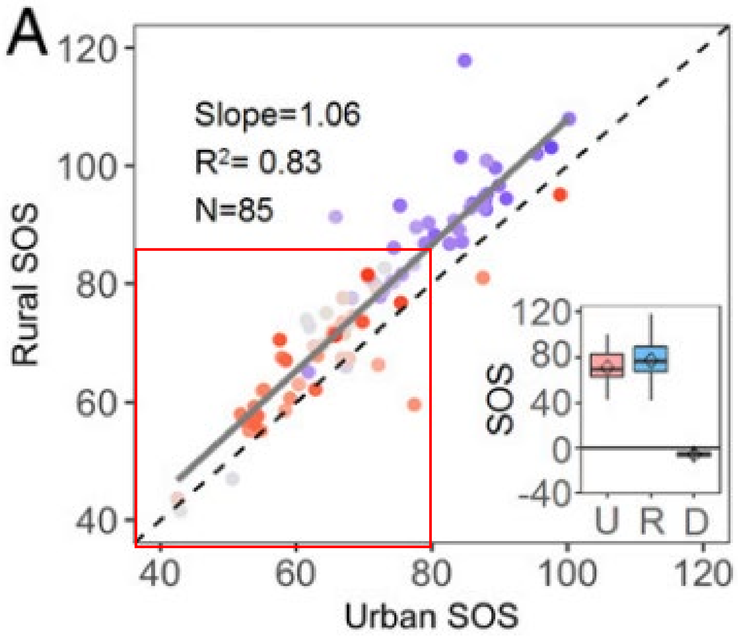
Results

SOS

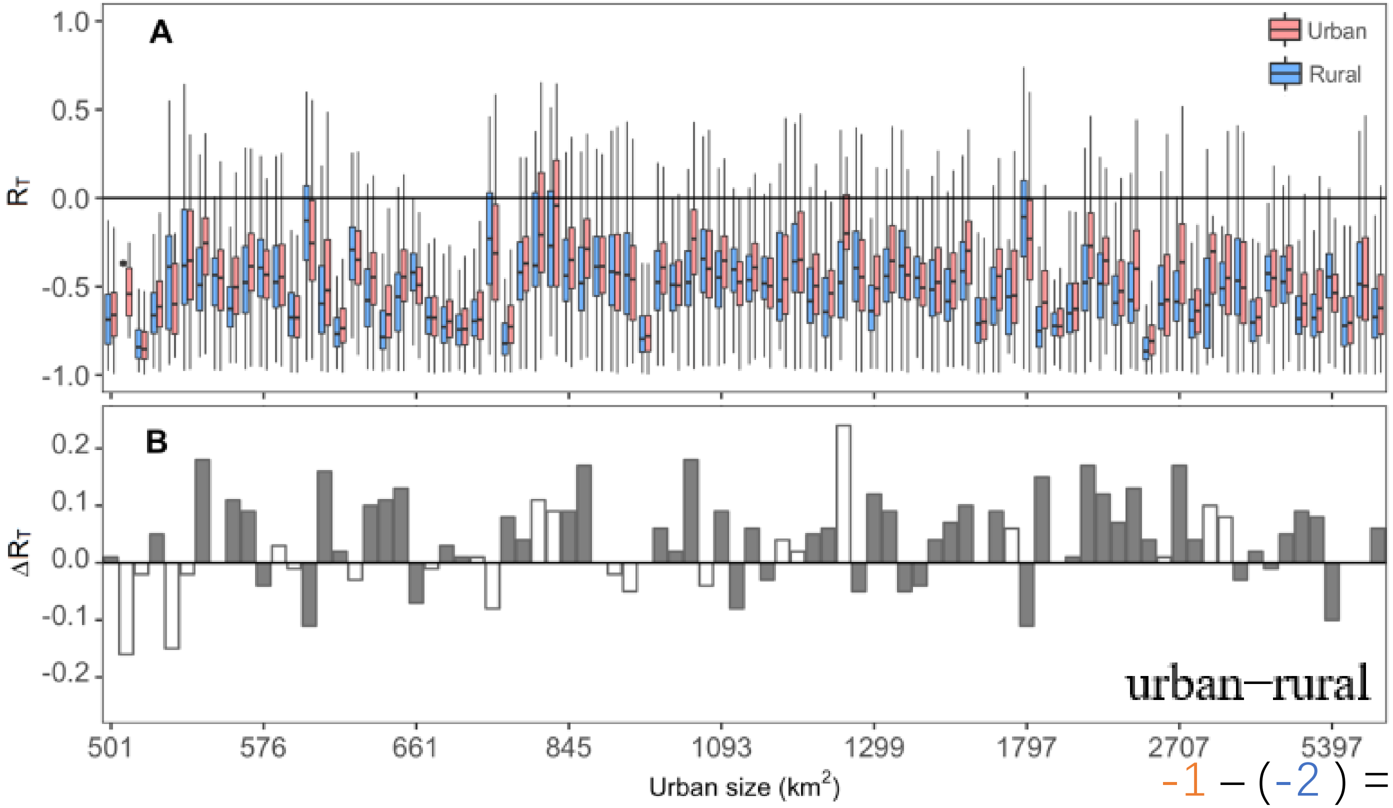




The SOS was 6.1 ± 6.3 d (mean ± SD) earlier in urban areas (SOS: 71.3 ± 13.1 d of year) than in corresponding rural areas (SOS: 77.4 ± 15.2 d of year) with a slope of 1.06 ($P < 0.001$).

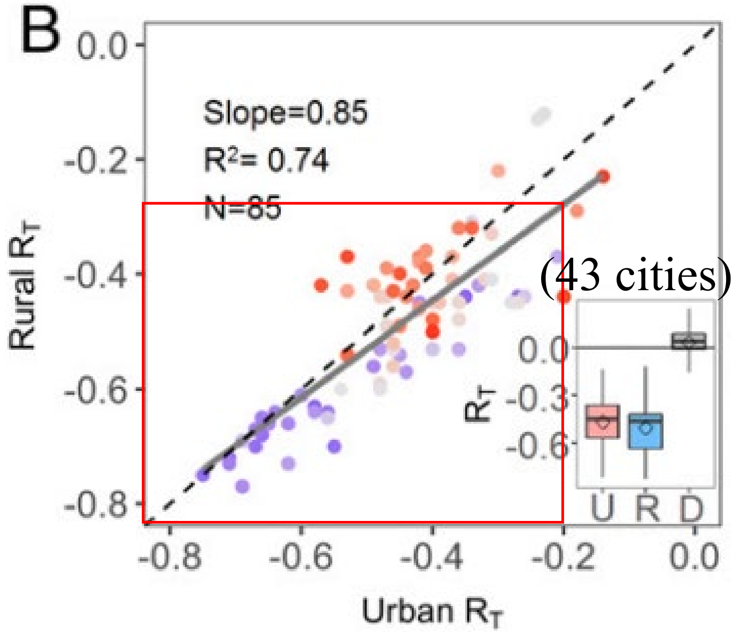
Results

R_T



-1 – (-2) = 1

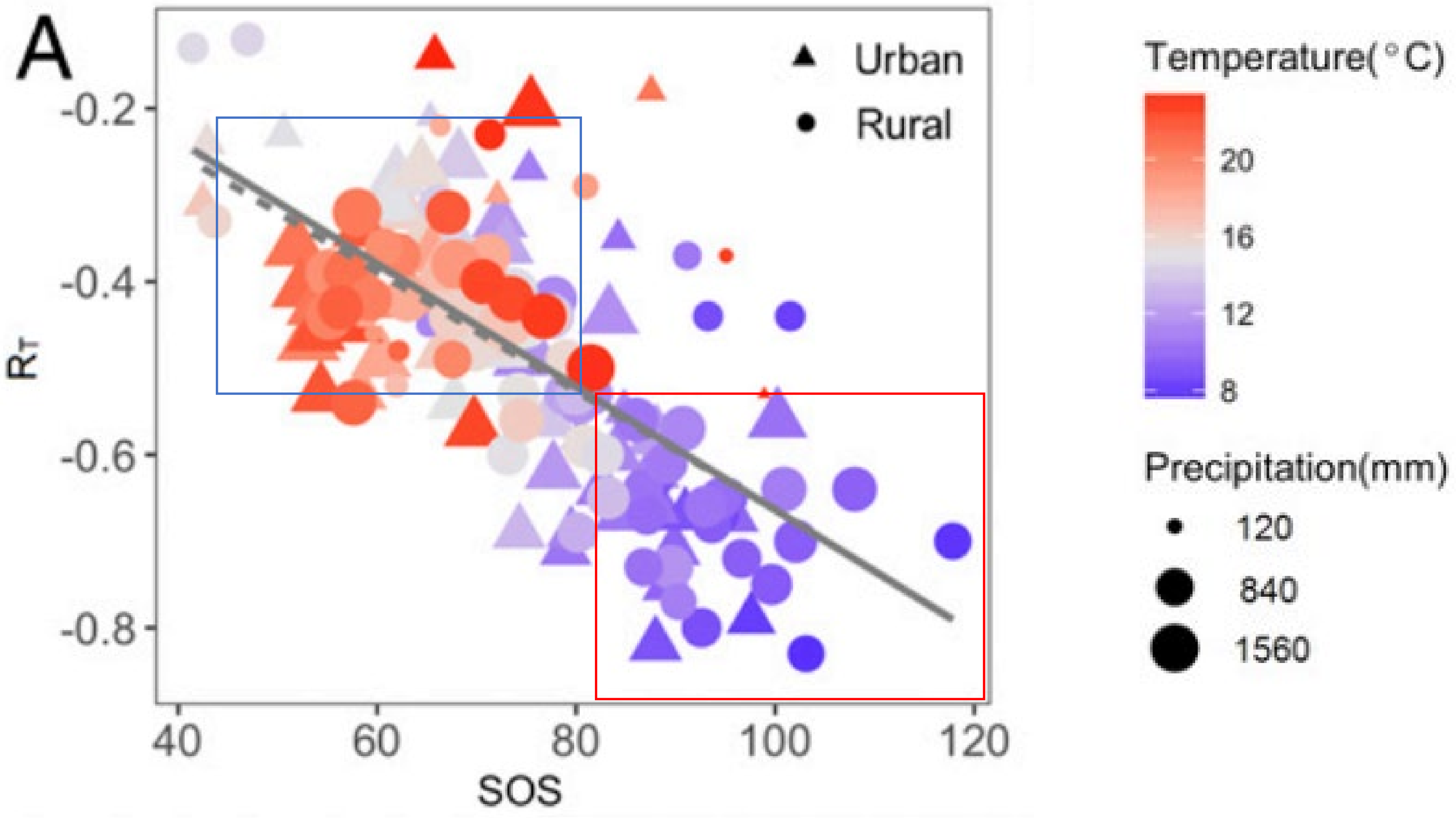
|小| |大|



The R_T was 0.03 ± 0.07 weaker in urban than in corresponding rural areas with slope of 0.85 (P < 0.001) .

城市里的物候对温度的敏感性是比起农村要低的

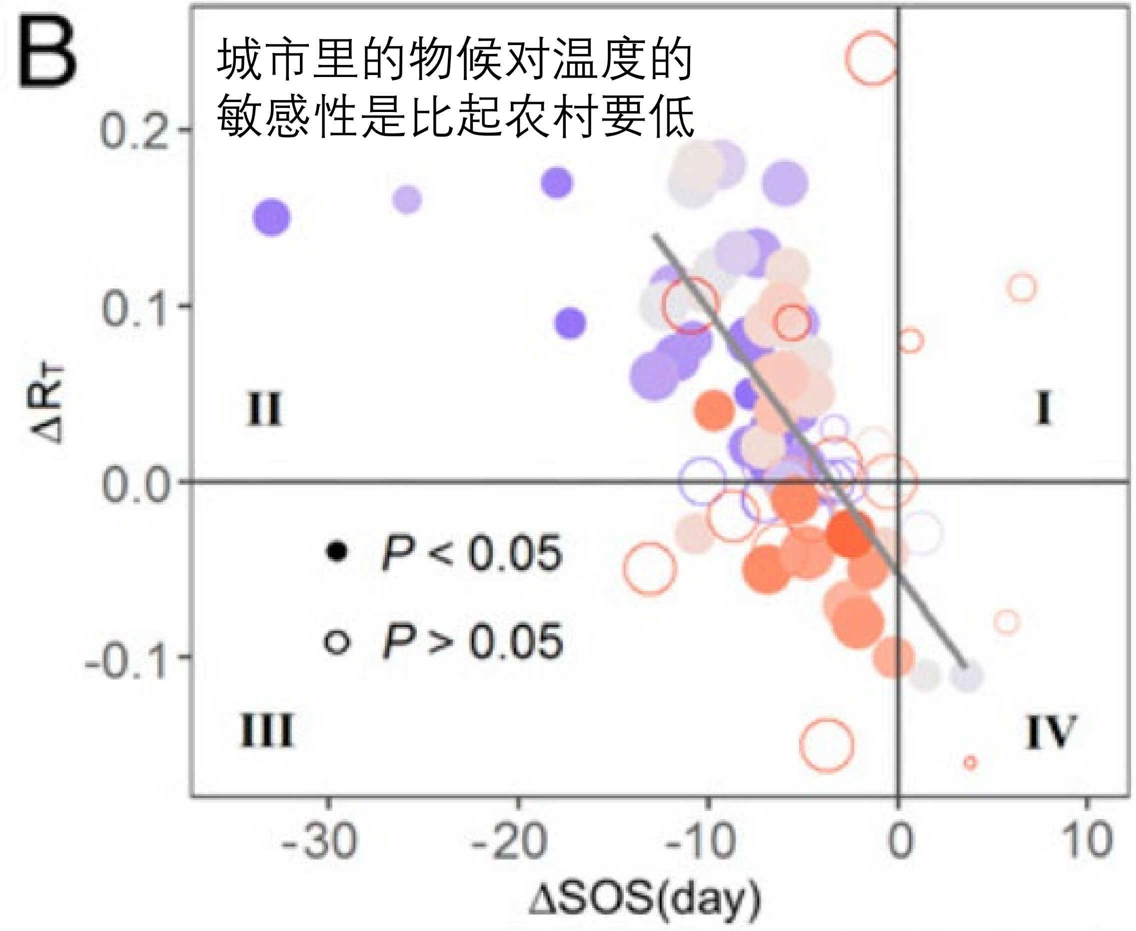
Results

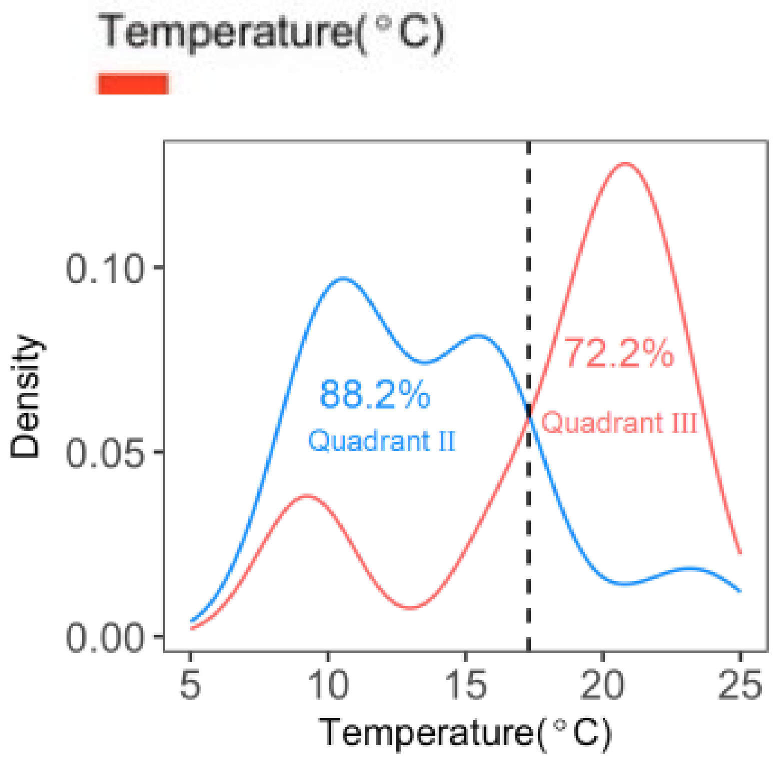


☐ Relationship

- ➢ The SOS significantly advanced with an increase in annual mean air temperature (Tavg slope = -1.98 d/°C)
- ➢ However, the magnitude of Rt significantly decreased (less negative) with the advancement of SOS

Results



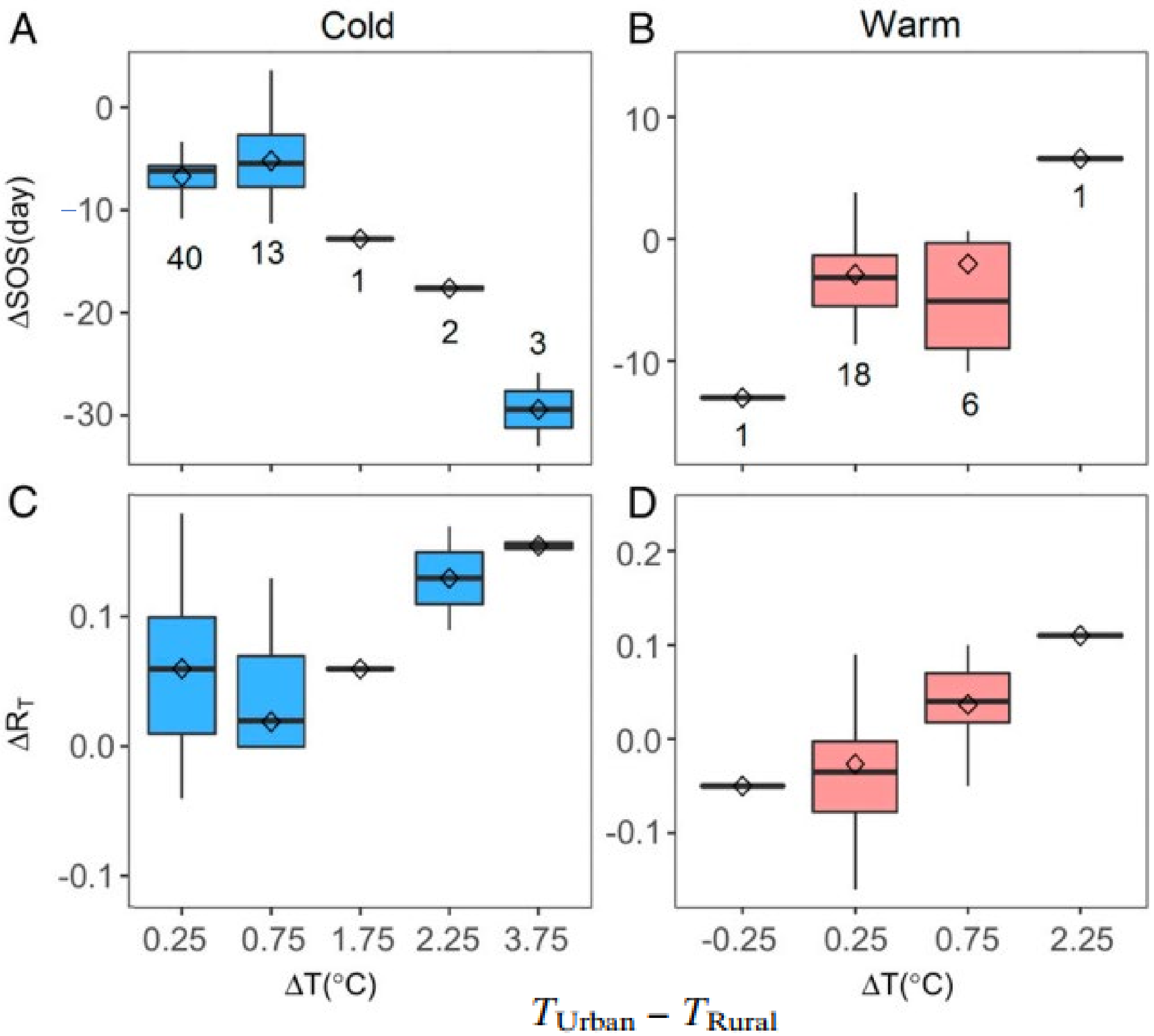


□ $\Delta R_T = R_T$ urban−rural

- The urban−rural difference in ΔR_T significantly negatively correlated with the ΔSOS.
- The magnitude of ΔR_T increased for cities in quadrant II and decreased for cities in quadrant III | 17.3°C

Results

Above the background climates, Cold and Warm



- All of the cities (98%) showed significant UHI effects
- Regions separated by 17.3 °C as the threshold.

Cold: ΔSOS and Δ R_T significantly decreased at -7.0 d/°C and increased at 0.04/°C.

Warm: The UHII significantly strengthened the urban Rt reduction at 0.07/°C but not SOS. ΔR_T was negative when ΔT was less than 0.5 °C.

Discussion

- The study provides direct evidence urban warming not only advanced SOS but reduced the magnitude of SOS response to temperature in 85 large US cities.

☐ Explain the reduced Rt magnitudes.

We sider four hypotheses:

(1)thermal budget percentage (2)insufficient chilling .

(3)reduced preseason length (4)photoperiod restriction

Discussion

Four Hypotheses

- Thermal budget percentage

  - Spring phenology more sensitive to temperature in colder, higher-latitude sites.

  - Small absolute changes in temperature constitute greater relative changes in thermal balance.

  - In rural areas, increase in temperature constitutes a larger magnitude for Rt than that for urban.

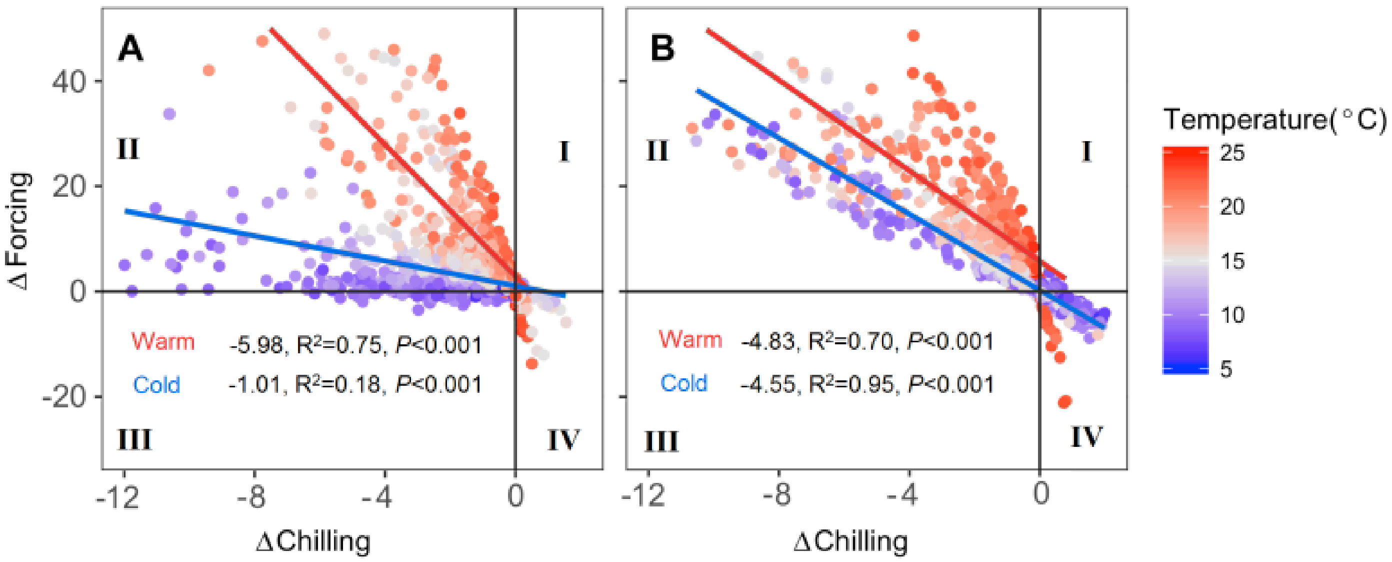
Discussion

Four Hypotheses

☐ Insufficient chilling

- The necessary chilling for dormancy break is not fully met.(e.g. under warm winters), Plant become less responsive to spring warming.

- The forcing process might be delayed or the forcing requirement might be increased. Leading to a decreased magnitude in the temperature response of SOS.



Discussion

Four Hypotheses

☐ Reduce preseason length

- The suggests climate warming reduces the magnitude of Rt simply reducing the length the preseason, due to a faster progression toward budburst in spring .
- However, we did not find significant changes in preseason length from urban to rural areas.
- The impacts of preseason length on Rt can be excluded in this study.

☐ Photoperiod

- Photoperiod has been proposed to restrict the advancement of phenology.
- However, we did not find evidence that a hard limit had been reached in this study.
- The impacts of preseason length on Rt can be excluded in this study during urban and rural.

Significance

Significance

Cities and their associated urban heat islands are ideal natural laboratories for evaluating the response of plant phenology to warming conditions. In this study, we demonstrate that the satellite-derived start of season for plants occurred earlier but showed less covariation with temperature in most of the large 85 cities across the conterminous United States for the period 2001–2014. The results show a reduction in the response of urban phenology to temperature and imply that, in nonurban environments, the onset of spring phenology will likely advance but will slow down as the general trend toward warming continues.

Thank you for your time!