Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center

pmod wrc

Cherry Blossom

Evidence for solar forcing on the terrestrial climate

Prof. Dr. Werner Schmutz
PMOD/WRC

IPC-XIII September/October 2021

Three science questions

Q Did the Sun influence the climate in the past?

A *Yes, with 99.99% probability*

Q Have we observed the Sun to influence the terrestrial climate?

A *No. TSI is stable since we measure it from space*

Q Could the Sun have an influence on the future climate?

A *Yes, potentially. If the Sun is decreasing its TSI …*

~~Three~~ One science questions

pmod wrc

Q Did the Sun influence the climate in the past?

A *Yes, with 99.99% probability*

Focus of today's talk

Extract from:

Search for:
Schmutz JSWSC 2021

J. Space Weather Space Clim. 2021, **11**, 40

https://doi.org/10.1051/swsc/2021016

JSWSC

Available online at:
www.swsc-journal.org

Topical Issue - 10 years of JSWSC

AGORA – SCIENTIFIC REFLECTIONS OPEN ACCESS

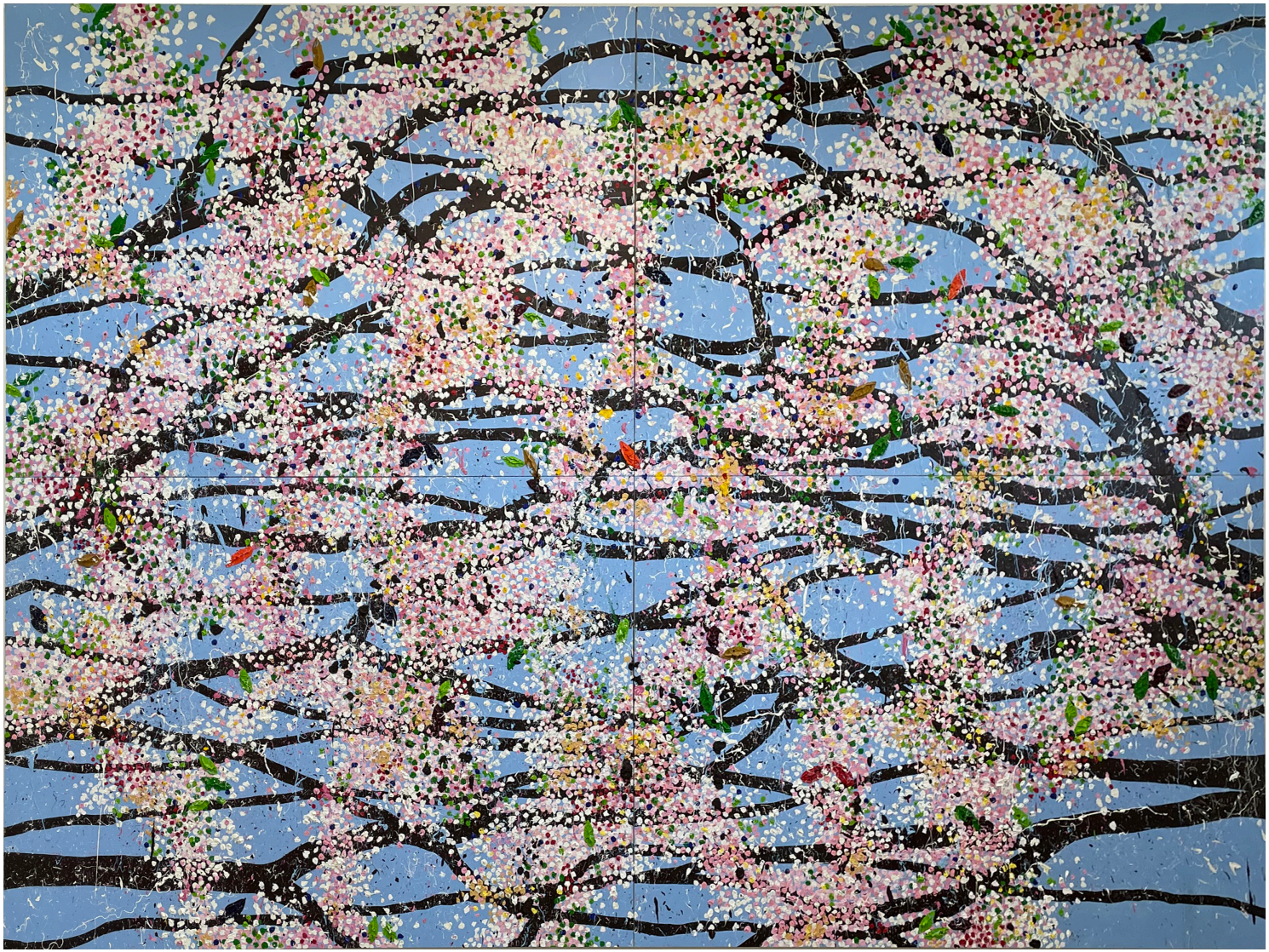
Changes in the Total Solar Irradiance and climatic effects

Werner K. Schmutz*

Physikalisch-Meteorologisches Observatorium Davos World Radiation Centre, Dorfstrasse 33, 7260 Davos Dorf, Switzerland

Received 31 December 2020 / Accepted 16 April 2021

Cherry Blossom

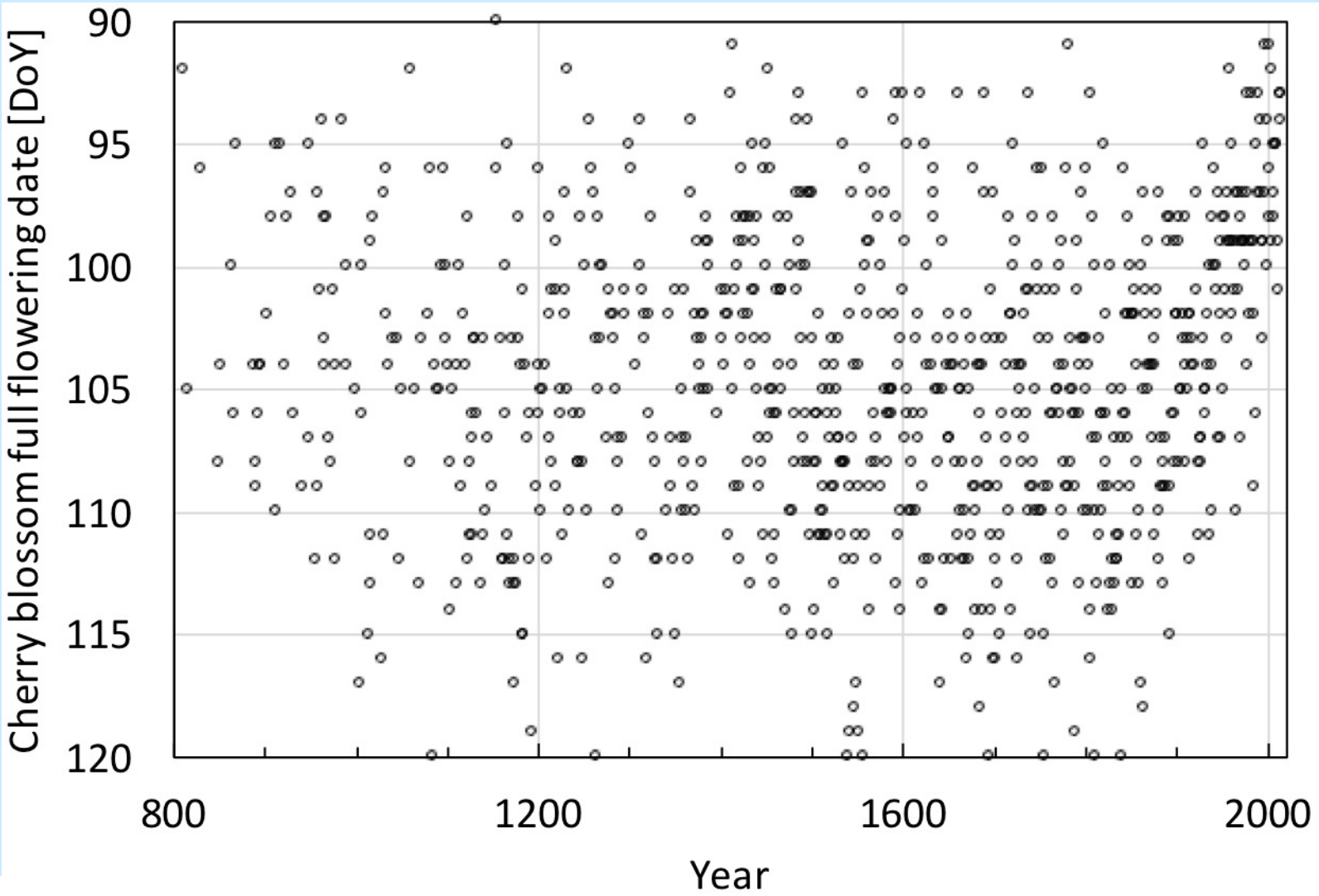


Damian Hirst 2019, Oil on canvas, 5.49 m x 7.32 m

“Greater Love Has No-One Than This Blossom”

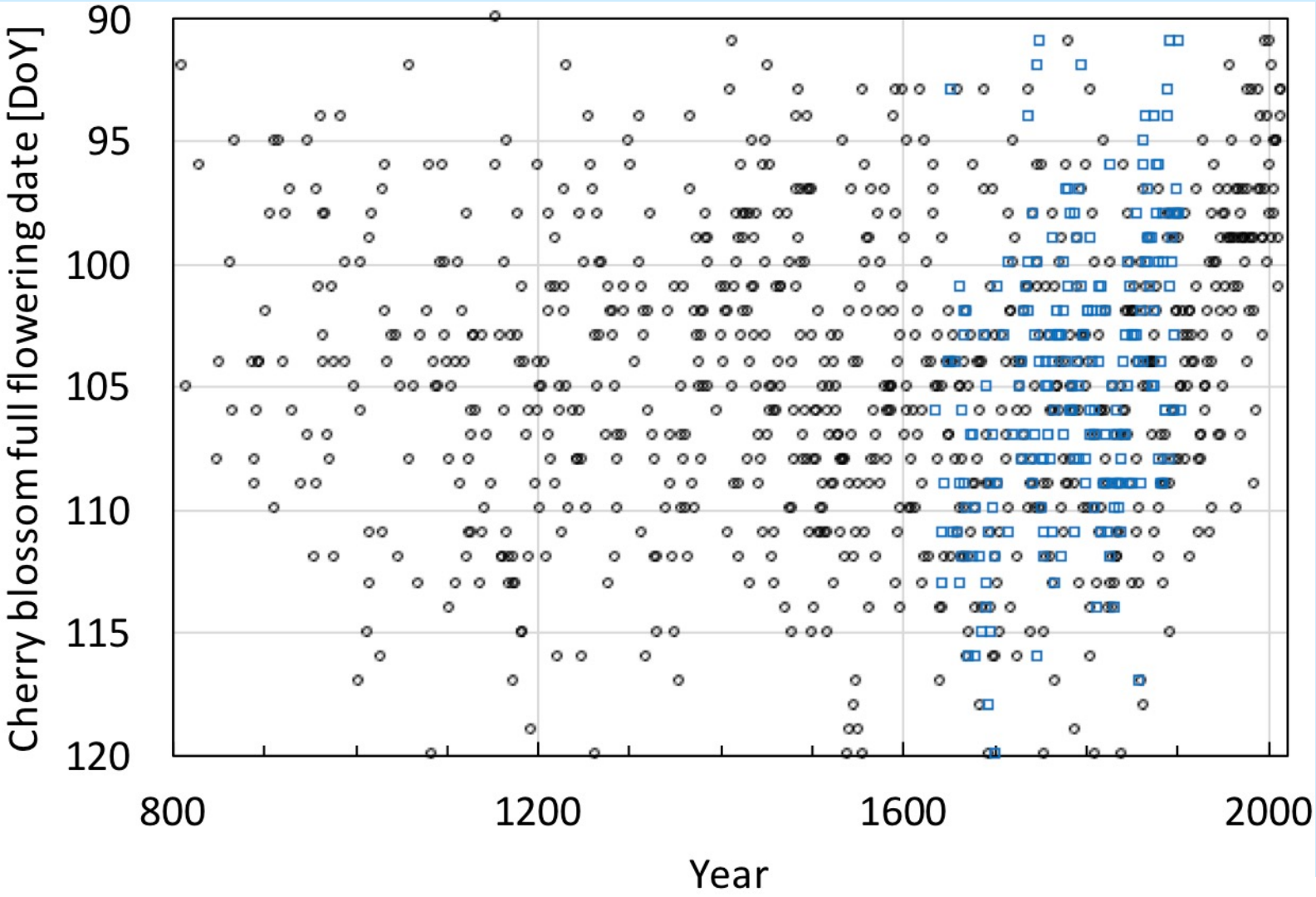
A 1200-year record of cherry blossom dates

pmod wrc



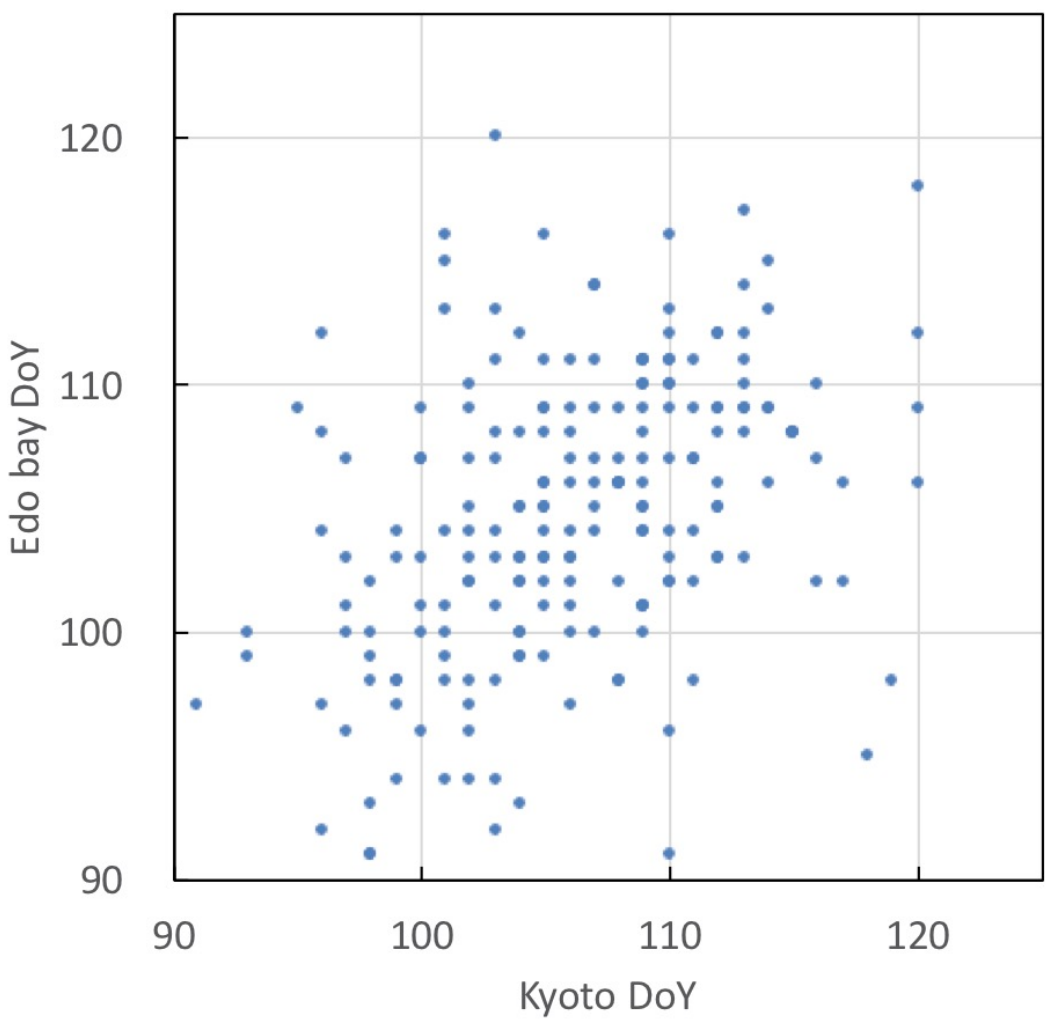
Kyoto, Japan (Aono & Kazui, 2008)

A 1200-year record of cherry blossom dates



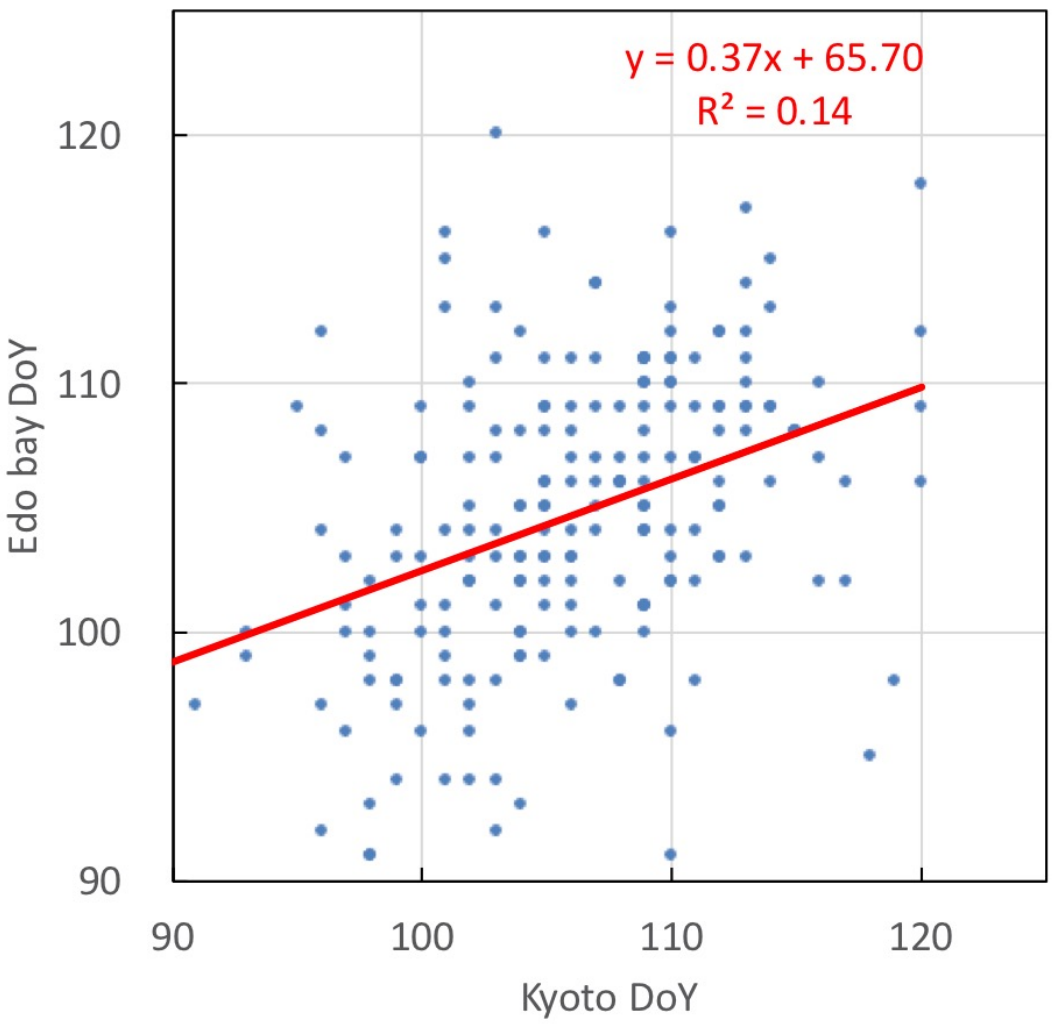
Kyoto, Japan (Aono & Kazui, 2008) Edo bay (Aono, 2015)

A 260-year record of cherry blossom dates



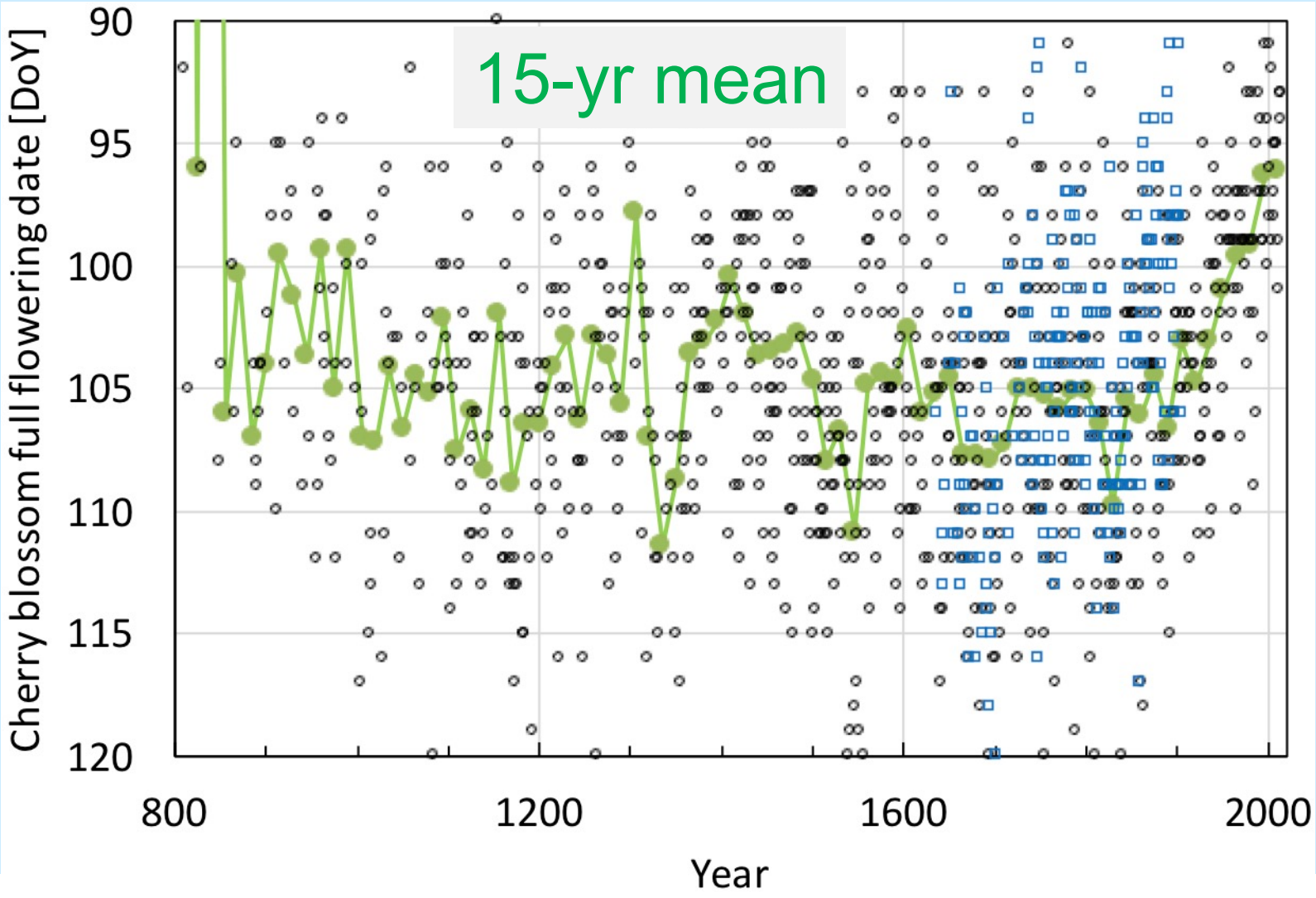
Kyoto, Japan (Aono & Kazui, 2008) Edo bay (Aono 2015)

A 260-year record of cherry blossom dates



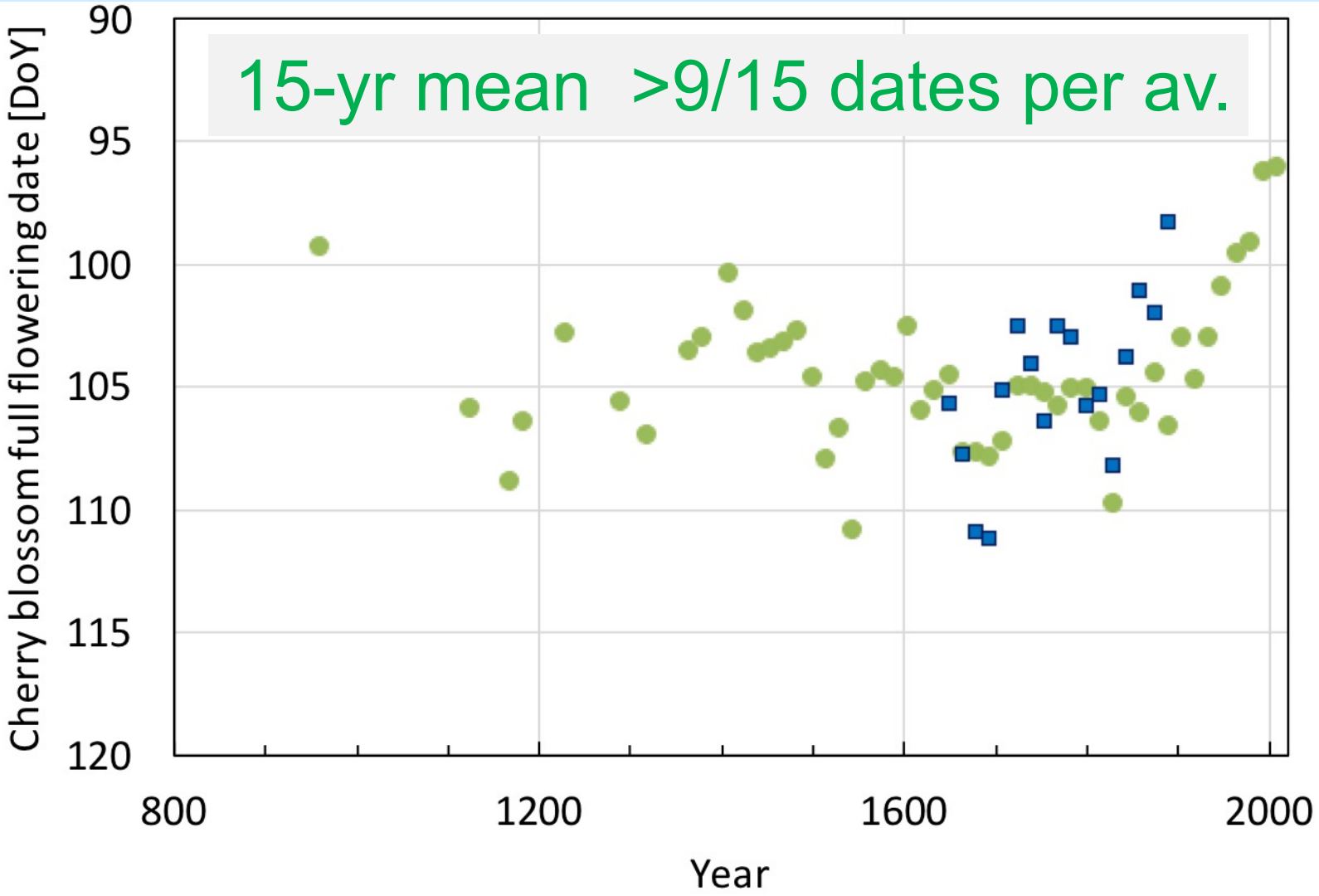
Kyoto, Japan (Aono & Kazui, 2008) Edo bay (Aono 2015)

A 1200-year record of cherry blossom dates



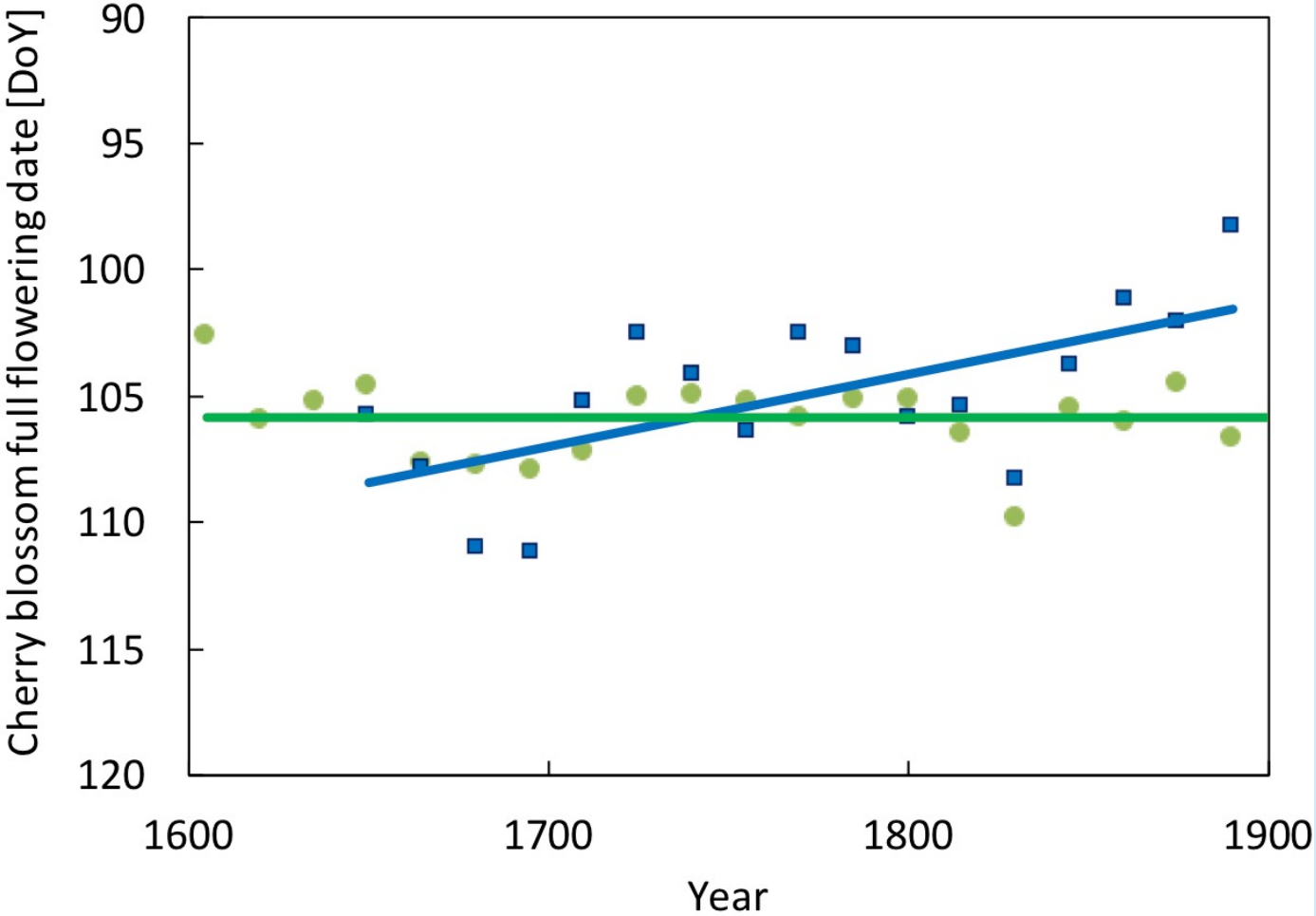
Kyoto, Japan (Aono & Kazui, 2008)

A 1200-year record of cherry blossom dates



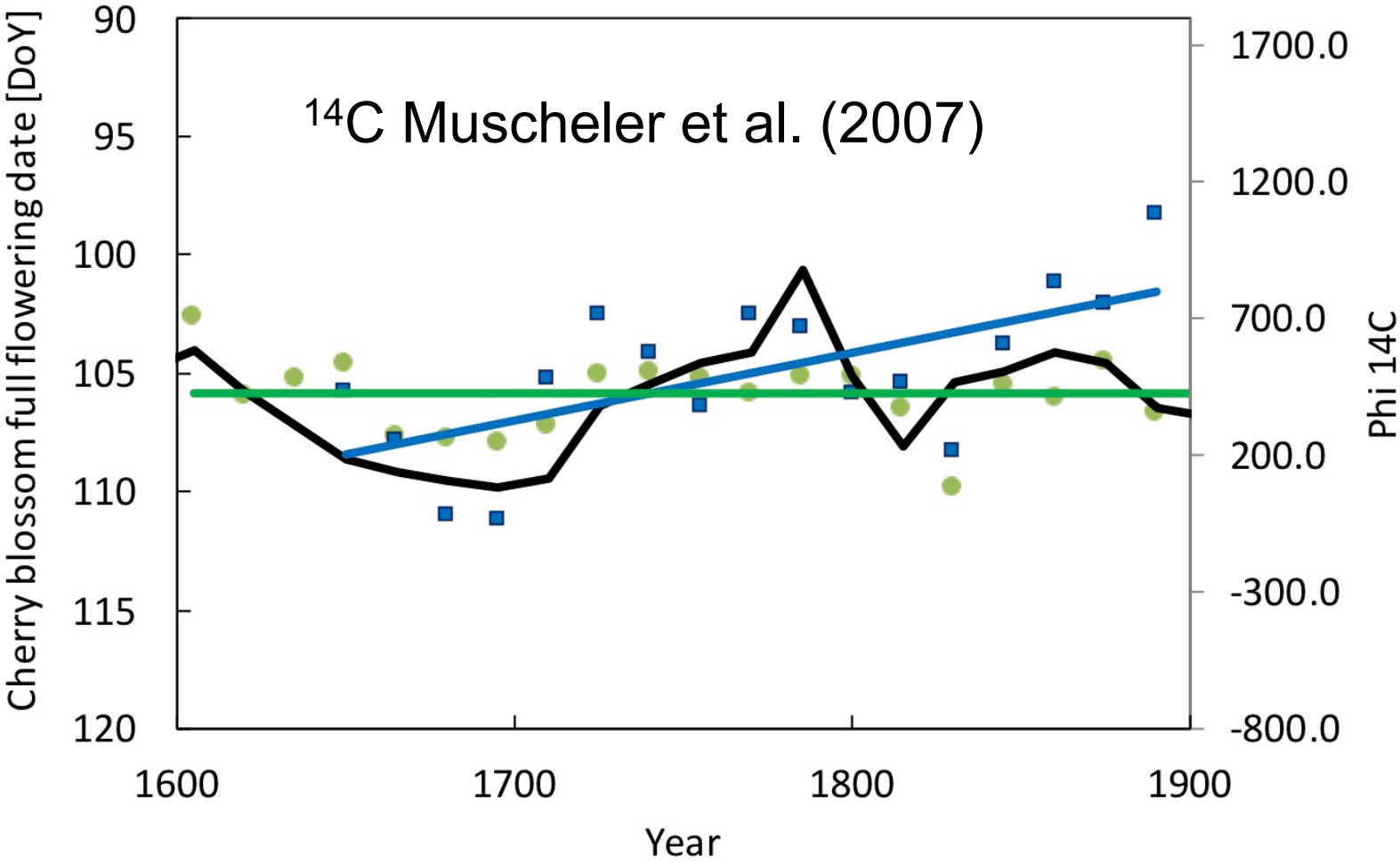
Kyoto, Japan (Aono & Kazui, 2008) Edo bay (Aono (2015)

A 300-year record of cherry blossom dates



Kyoto, Japan (Aono & Kazui, 2008) Edo bay (Aono (2015)

Comparing to solar activity



Kyoto, Japan (Aono & Kazui, 2008) Edo bay (Aono, 2015)

A historic climate-record correlates with a solar activity proxy

pmod wrc

Cherry blossom full flowering date in Japan

Solar magnetic modulation of radionuclide production rates

A historic climate-record correlates with a solar activity proxy

Past climate variations

Solar activity variations

Physical connection

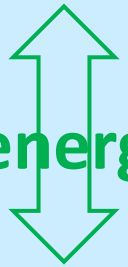
Past climate variations

Terrestrial energy equation

Solar activity variations

Physical connection

Near ground level temperatures [°C]



Terrestrial energy equation

Solar irradiance [W/m^2]

Terrestrial energy equation

Solar radiation energy reaching Earth's surface

Surface radiation energy leaving Earth

$$\pi \mathcal{R}_{\oplus}^{2}\, \mathcal{S}_{\odot}(1 - \mathcal{A}_{\oplus} - \alpha) = 4\pi R_{\oplus}^{2}\, \sigma T_{\oplus}^{4}\, (1 - \mathcal{G}_{\mathrm{eff}})$$

S	*Solar irradiance*	*1361 W/m²*
T	*Terrestrial surface temperature*	*288 K (15 °C)*
R	*Terrestrial radius*	
A	*Albedo*	*29.4 %*
α	*Absorption of incoming radiation*	*23.5 %*
G_{eff}	*Effective greenhouse effect*	*59 %*

Impact of solar irradiance variations

$$\frac{\partial T_\oplus}{\partial \mathcal{S}_\odot} = \frac{\partial}{\partial \mathcal{S}_\odot}\left(\sqrt[4]{\frac{(1-\mathcal{A}_\oplus-\alpha)}{4\sigma(1-\mathcal{G}_{\text{eff}})}}\right)\cdot\sqrt[4]{\mathcal{S}_\odot} + \sqrt[4]{\frac{(1-\mathcal{A}_\oplus-\alpha)}{4\sigma(1-\mathcal{G}_{\text{eff}})}}\cdot\frac{\partial\sqrt[4]{\mathcal{S}_\odot}}{\partial \mathcal{S}_\odot},$$

with $\partial\mathcal{A}_\oplus/\partial\mathcal{S}_\odot = \partial\alpha/\partial\mathcal{S}_\odot = \partial\mathcal{G}_{\text{eff}}/\partial\mathcal{S}_\odot = 0$ ....

Impact of solar irradiance variations

$$\frac{\partial T_\oplus}{T_\oplus} = \frac{1}{4}\frac{\partial \mathcal{S}_\odot}{\mathcal{S}_\odot}$$

which yields

$$\partial T_\oplus = f\,\partial \mathcal{S}_\odot,$$

with $f = T_\oplus/(4\mathcal{S}_\odot) = 0.053\,°\mathrm{C}/(\mathrm{W/m^2})$

---

* Note that in climate sciences the incoming solar energy is usually related to the total Earths surface and thus, the solar irradiance is divided by a factor of four, $\hat{\mathcal{S}}_\odot = \mathcal{S}_\odot/4 = 340\ \mathrm{W/m^2}$, which yields a climate sensitivity $\partial T_\oplus = \hat{f}\,\partial \hat{\mathcal{S}}_\odot$, with a factor of four larger numeric value $\hat{f} = 0.21\ °\mathrm{C}/(\mathrm{W/m^2})$.

Physical connection

DoY ➔ Temperature

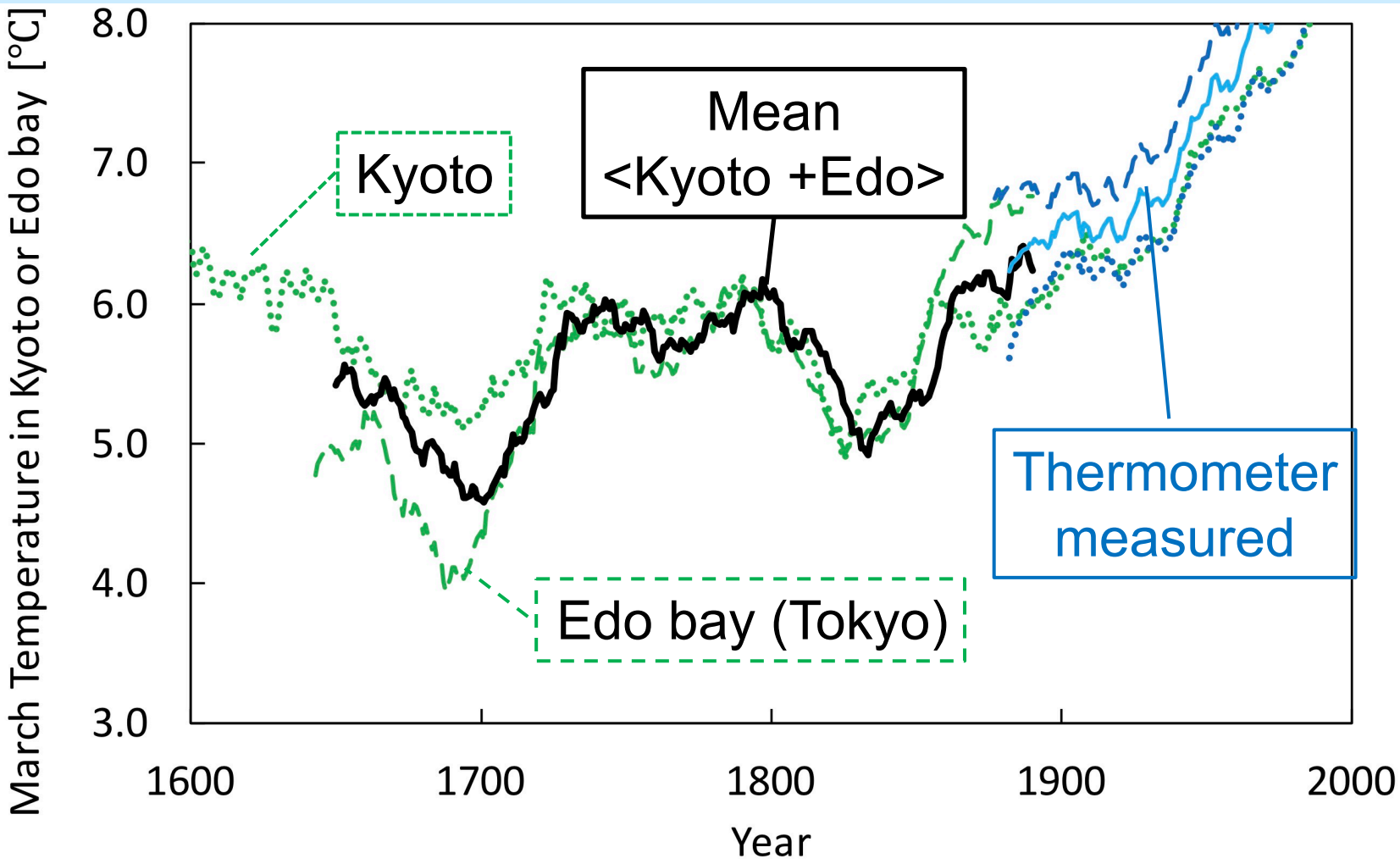
Aono & Kazui (2008); Aono (2015)

Terrestrial energy equation

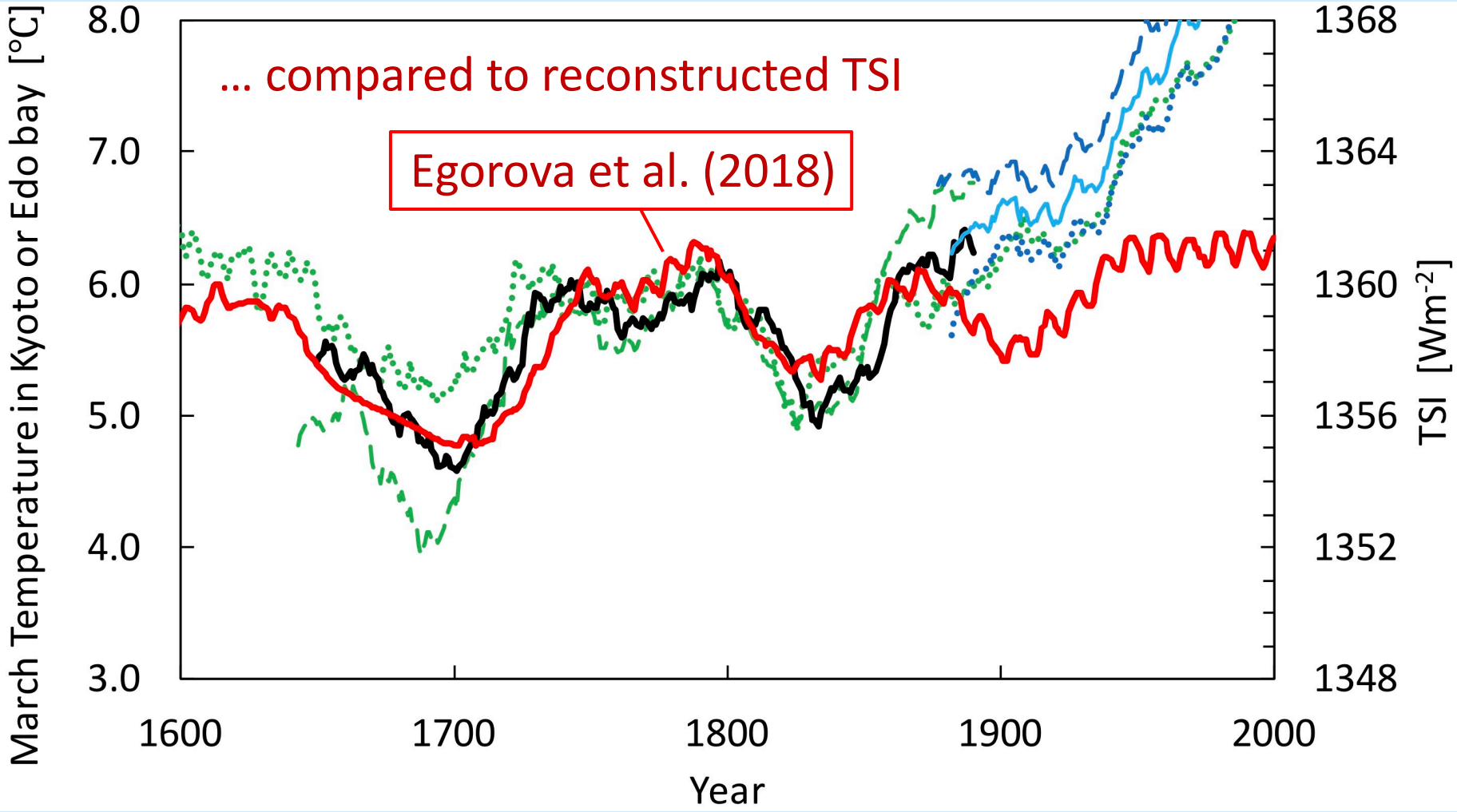
Egorova et al. (2018)

^{14}C, ^{10}Be Phi ➔ irradiance

Reconstructed March temperature from dates of cherry blossom (Japan)

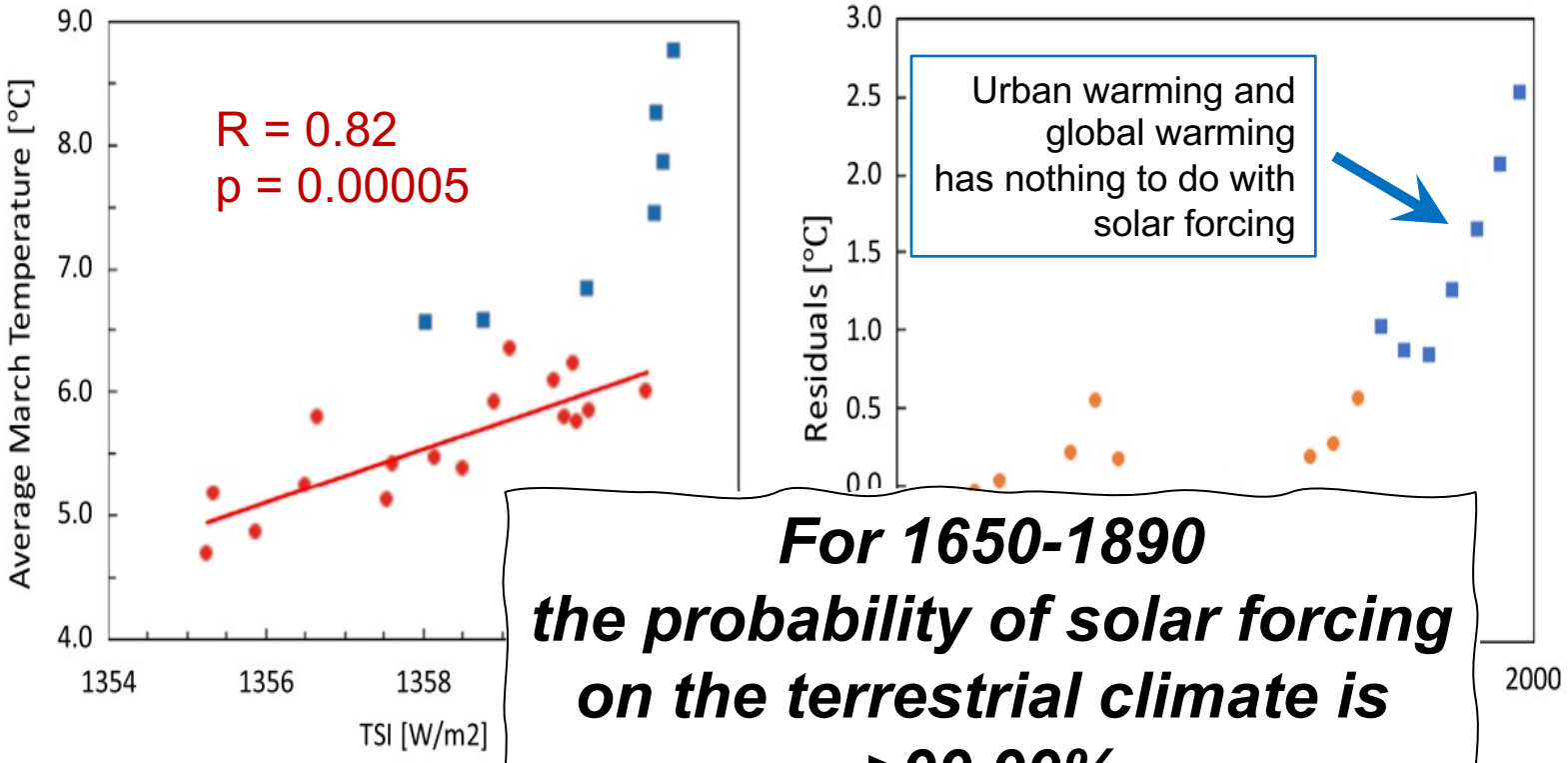


Reconstructed March temperature from dates of cherry blossom (Japan)



Schmutz (2021) JSWSC, in press

Correlation



For 1650-1890 the probability of solar forcing on the terrestrial climate is >99.99%

Fig. A.2. Left panel: 15-year averages of the mea[illegible]n the years 1650–1890 as a function of 15-year averages of TSI. The blue squares denote 15-year averages of thermometer measured temperatures in the time interval 1890–1995. Right panel: Residuals from the linear regression of the left panel (third row of Tab. A.1) as a function of time.

Fig A.2 of Schmutz (2021)

Comparing to solar activity

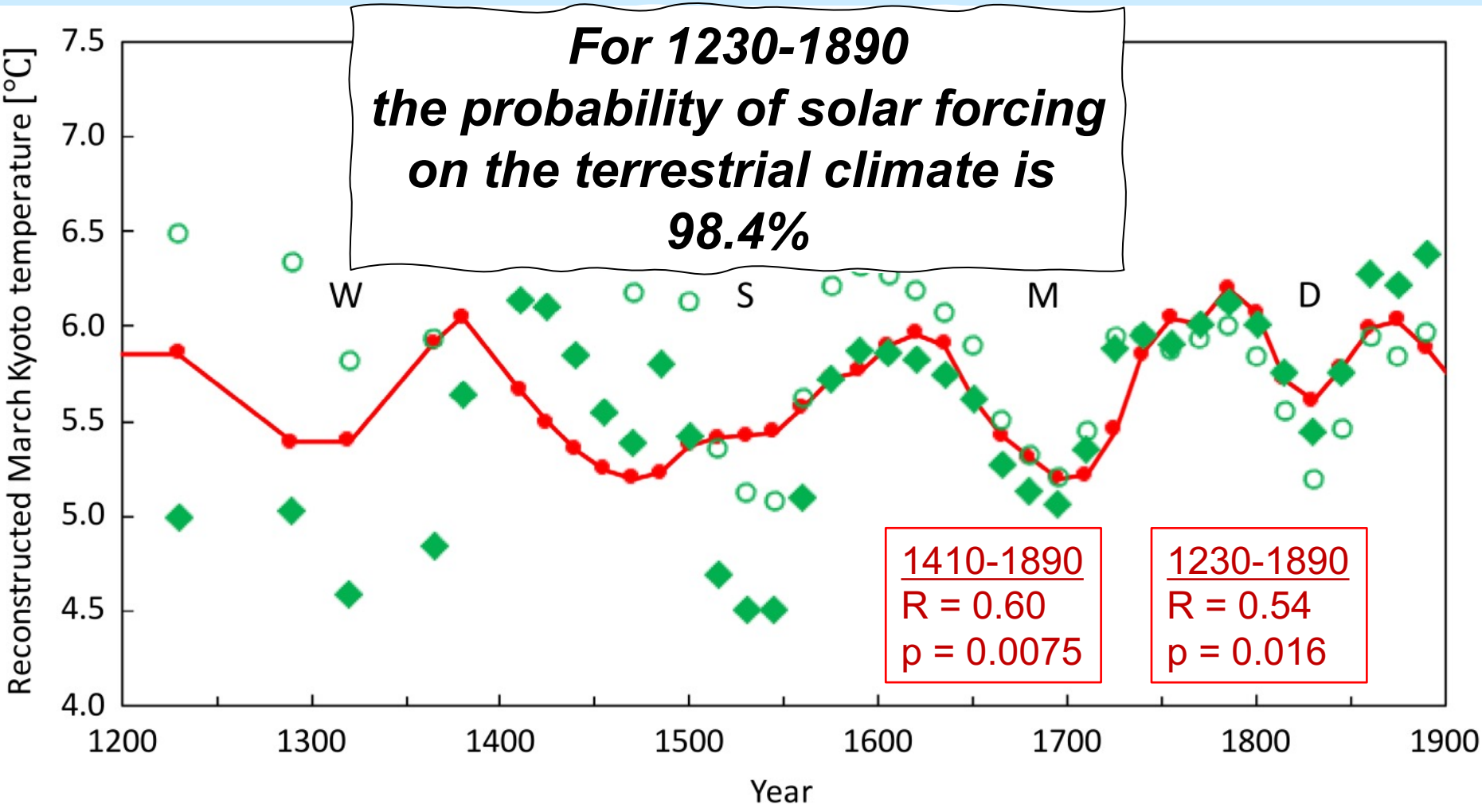


Fig A.3 of Schmutz (2021)

Three science questions

Q Did the Sun influence the climate in the past?

A *Yes, with 99.99% probability*

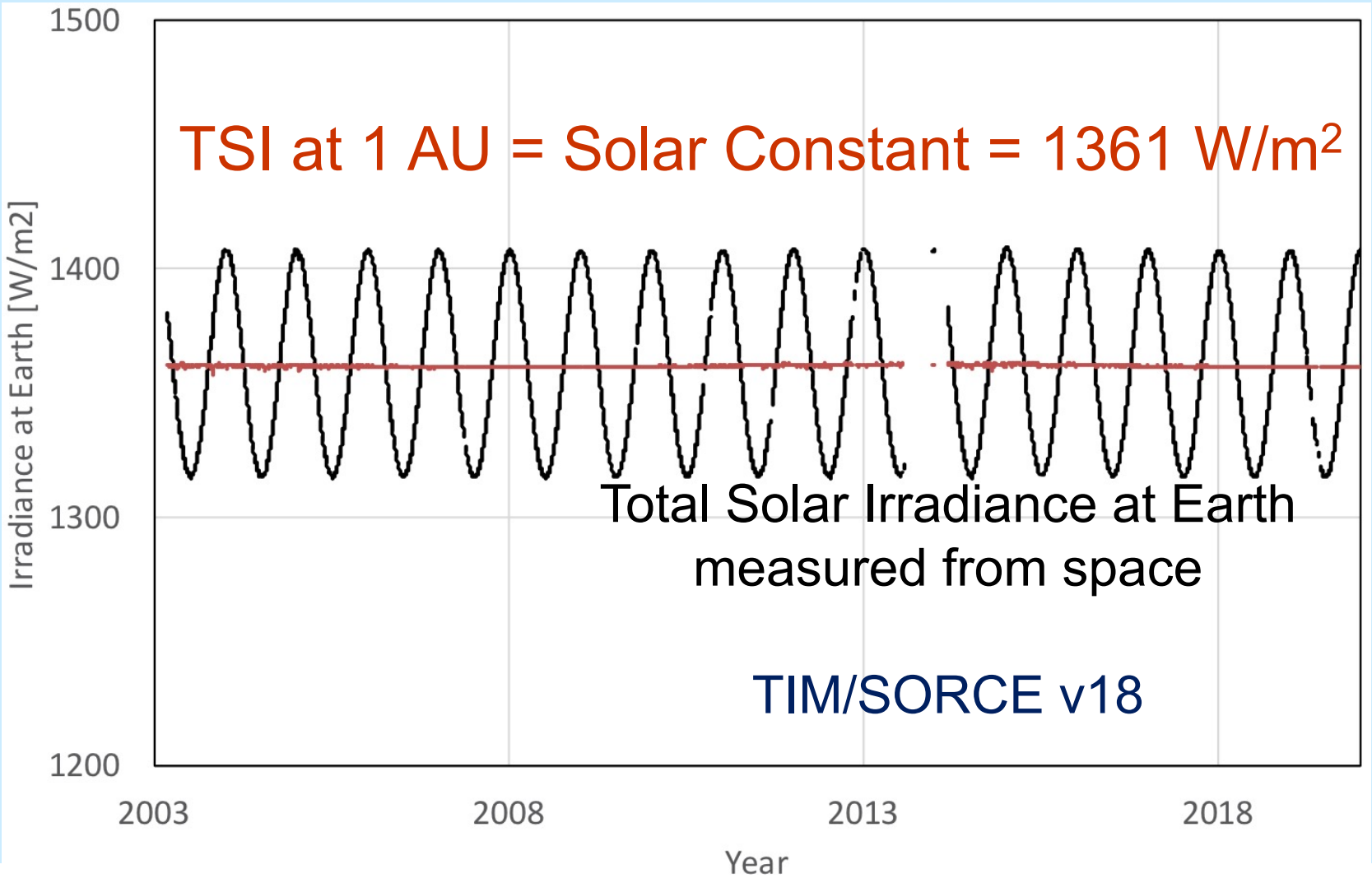
Q Have we observed the Sun to influence the terrestrial climate?

A *No. TSI is stable since we measure it from space*

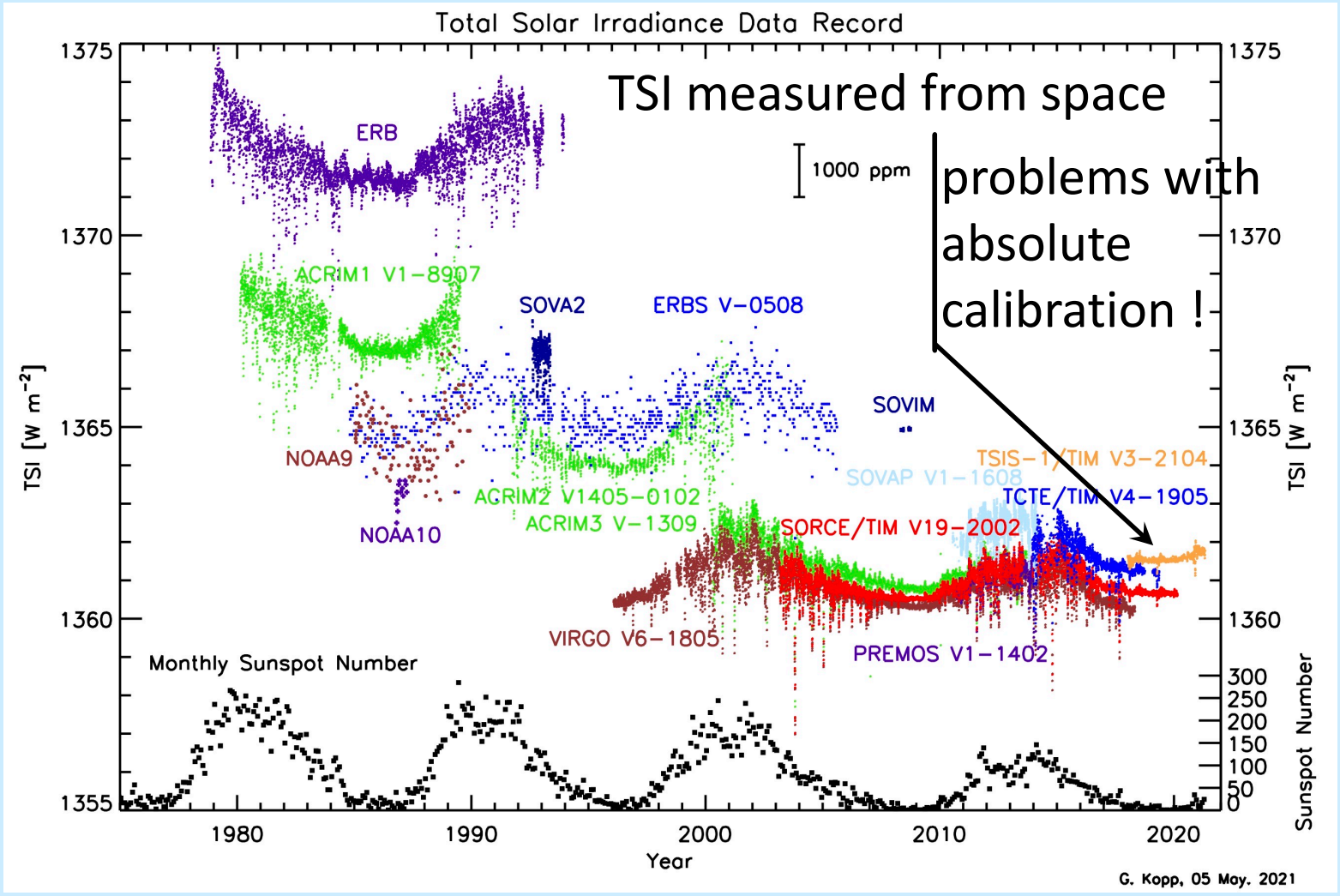
Q Could the Sun have an influence on the future climate?

A *Yes, potentially. If the Sun is decreasing its TSI …*

Have we observed the Sun to influence the terrestrial climate?

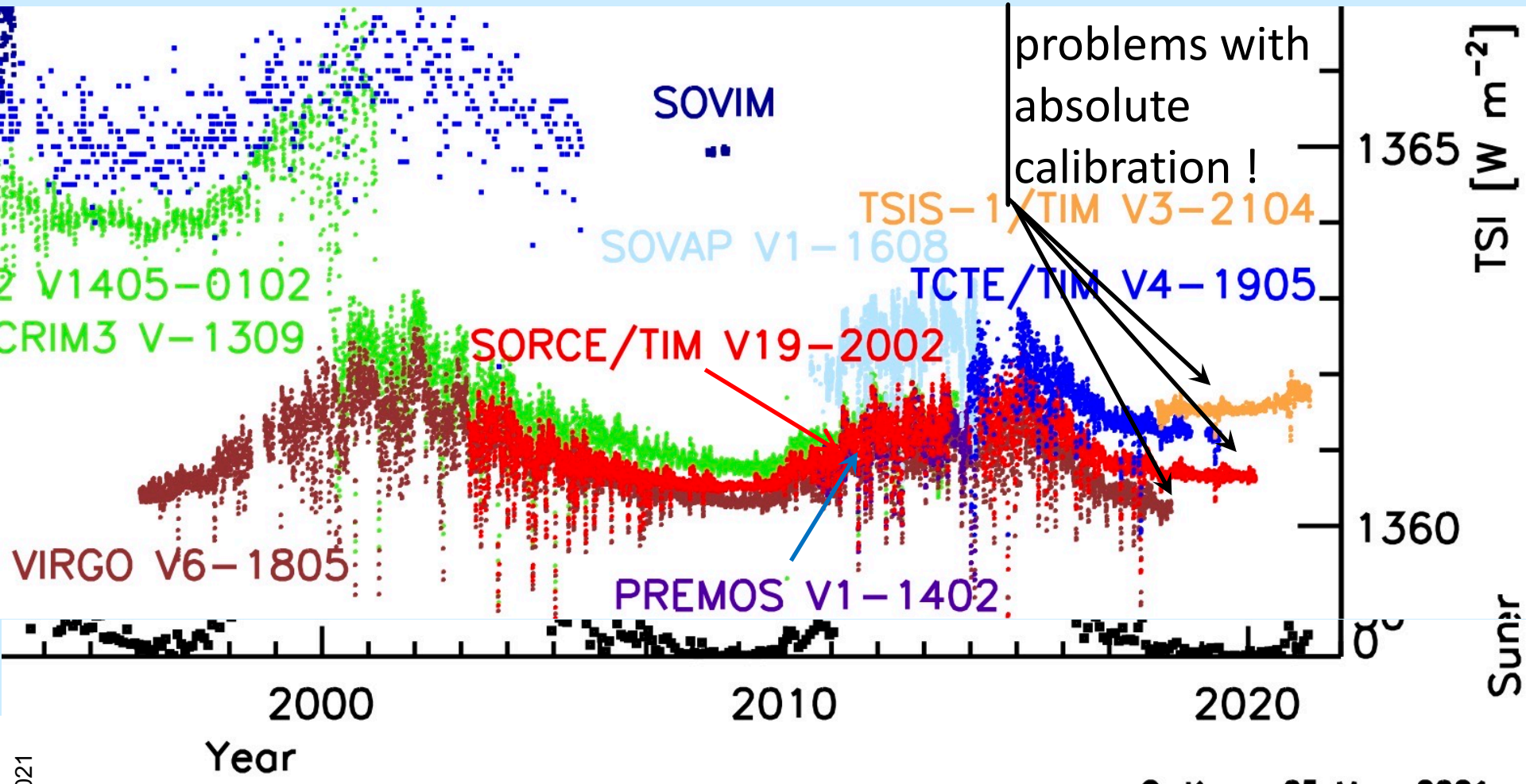


Have we observed the Sun to influence the terrestrial climate?

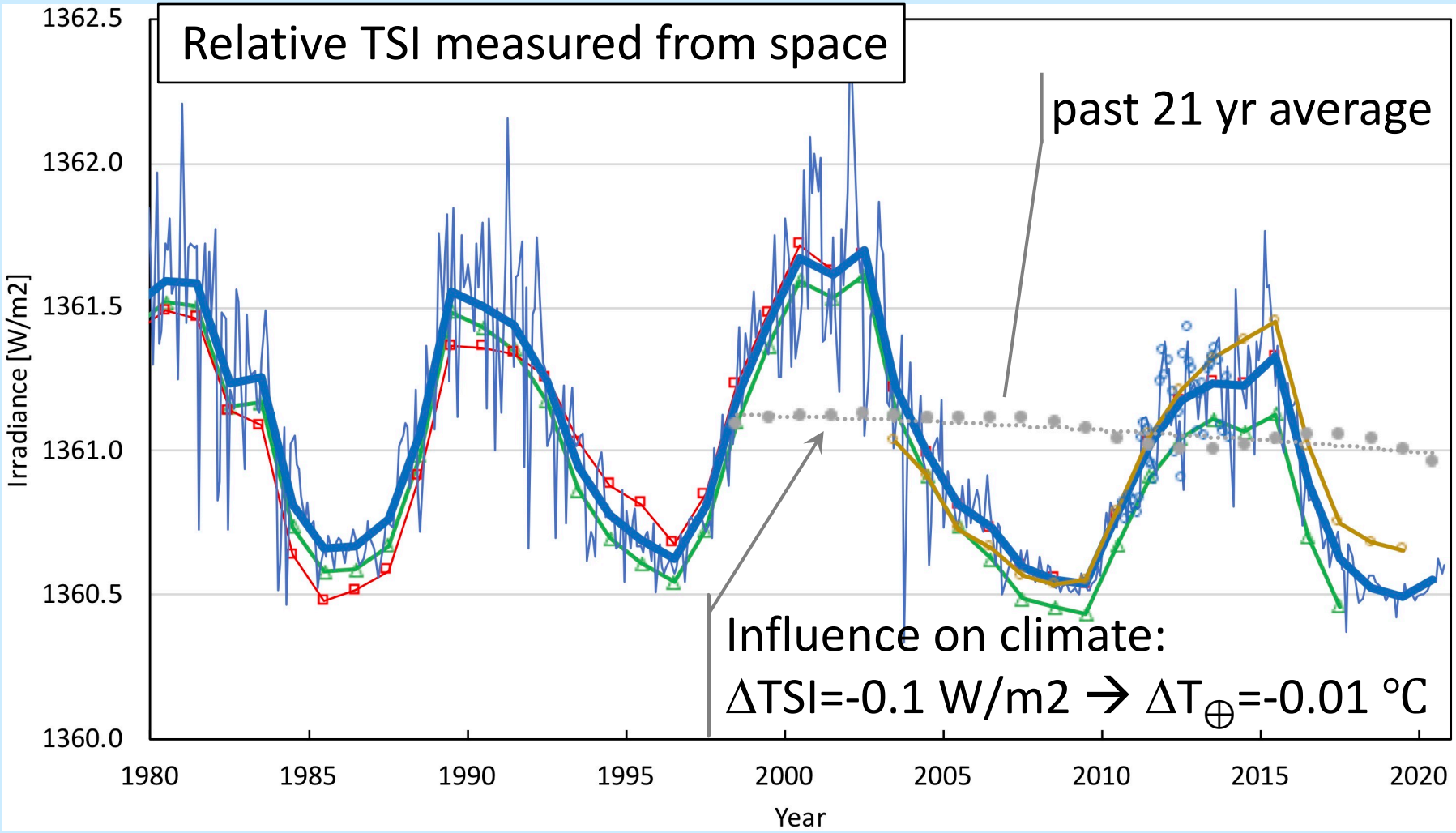


Have we observed the Sun to influence the terrestrial climate?

pmod wrc



Have we observed the Sun to influence the terrestrial climate?



Three science questions

Q Did the Sun influence the climate in the past?

A *Yes, with 99.99% probability*

Q Have we observed the Sun to influence the terrestrial climate?

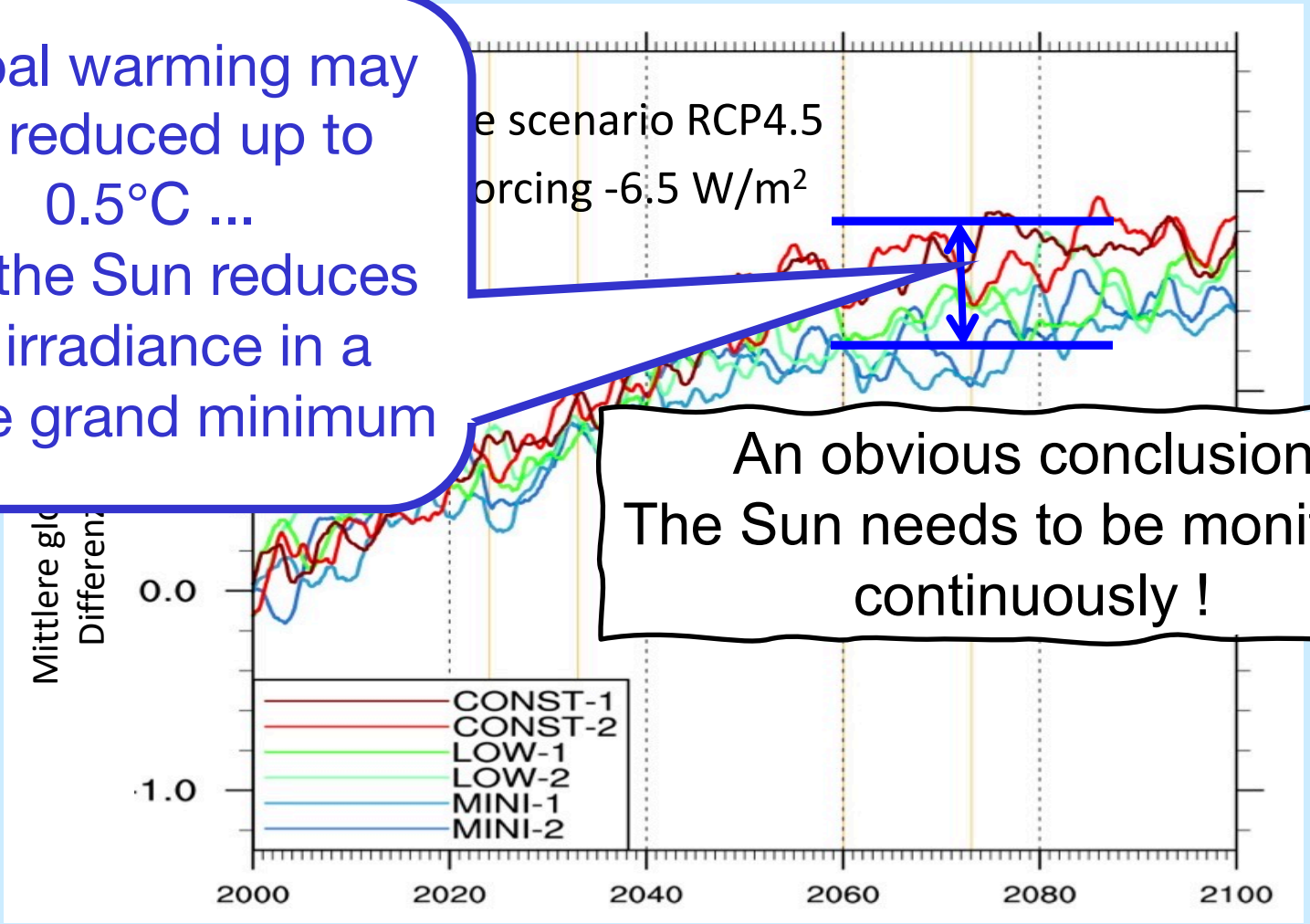
A *No. TSI is stable since we measure it from space*

Q Could the Sun have an influence on the future climate?

A *Yes, potentially. If the Sun is decreasing its TSI …*

Could the Sun have an influence on the future climate?

Global warming may be reduced up to 0.5°C ...
... if the Sun reduces its irradiance in a future grand minimum



An obvious conclusion:
The Sun needs to be monitored continuously !

Climate simulations:

Anet et al. 2013, Geophysical Research Letters, Vol. 40, 4420
Arsenovic et al. 2018, Atmos. Chem. Phys., Vol 18, 3469

pmod wrc

Thank you

for your attention !