

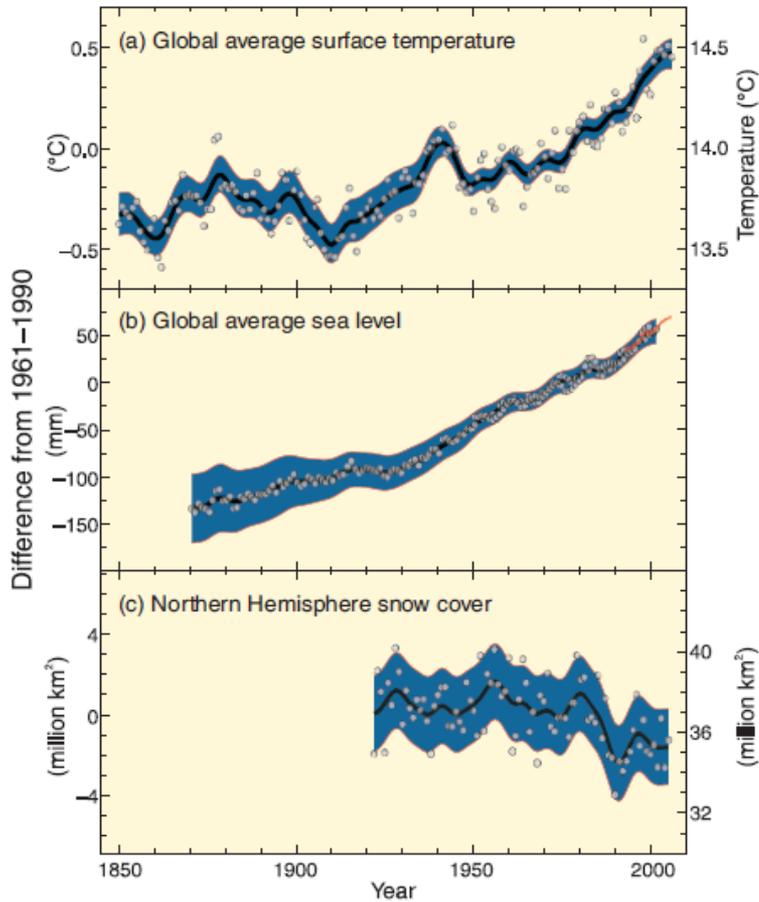
Climate change and pollen

Łukasz Grewling
Laboratory of Aeropalynology



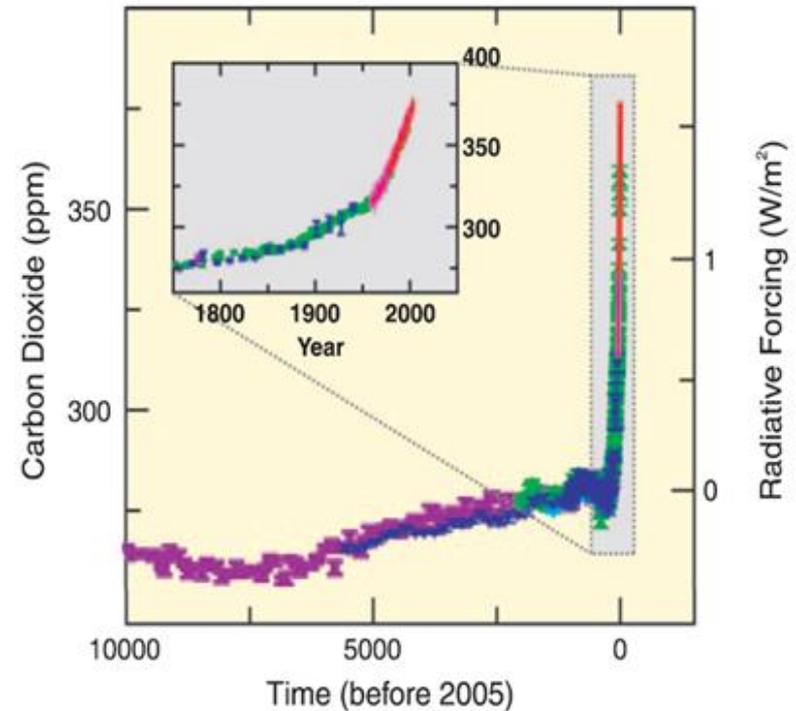
Mean global air temperature increased by 0.7°C during last 100 years

Changes in temperature, sea level and Northern Hemisphere snow cover



CO₂

Changes in GHGs from ice core and modern data



UDEL v3.01

Ann. mean 1990:2010 - 1901:1920

glb. mean: 0.74 degC

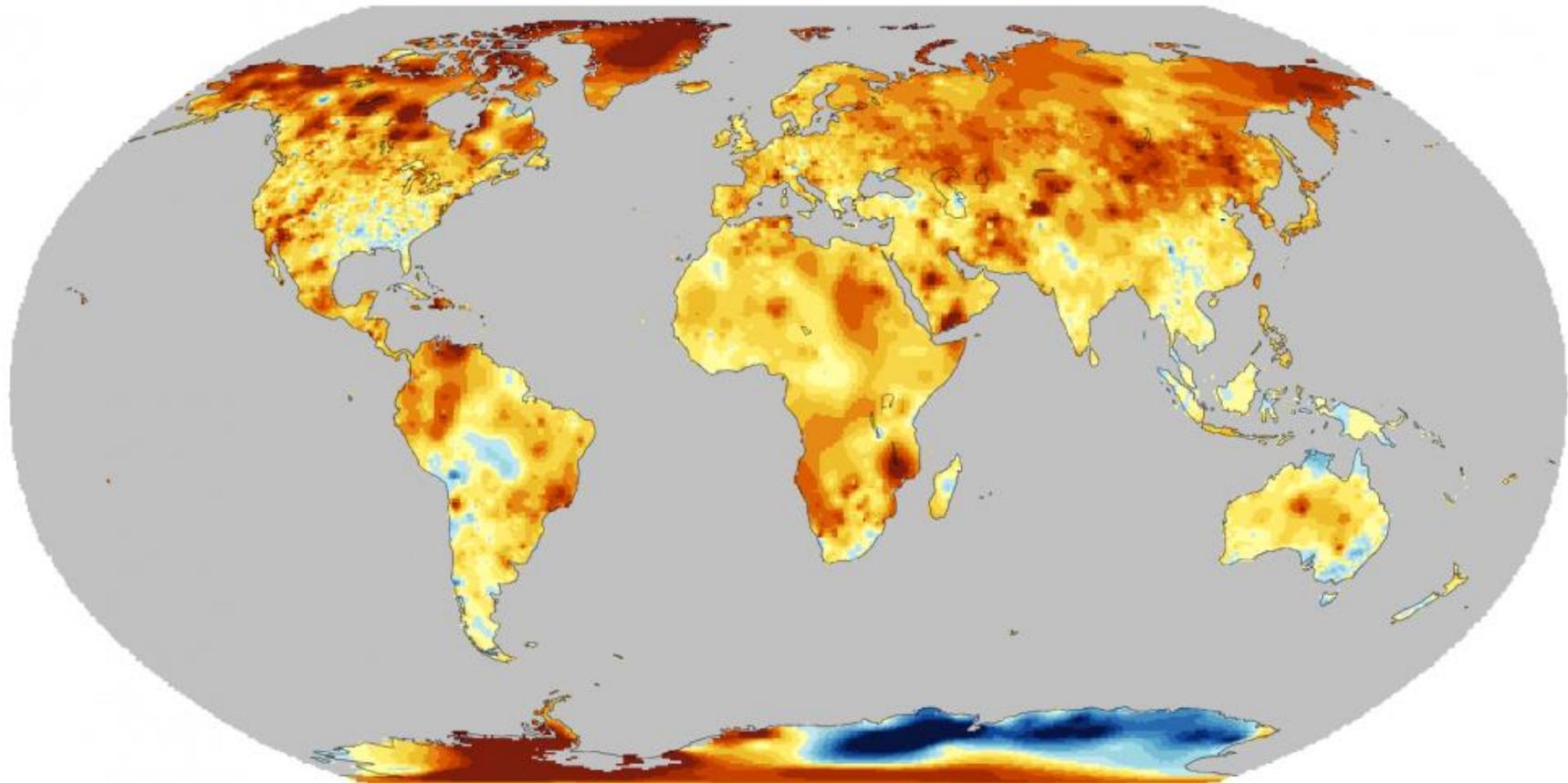
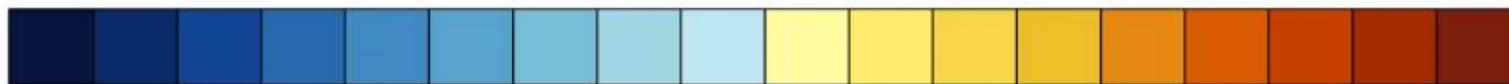
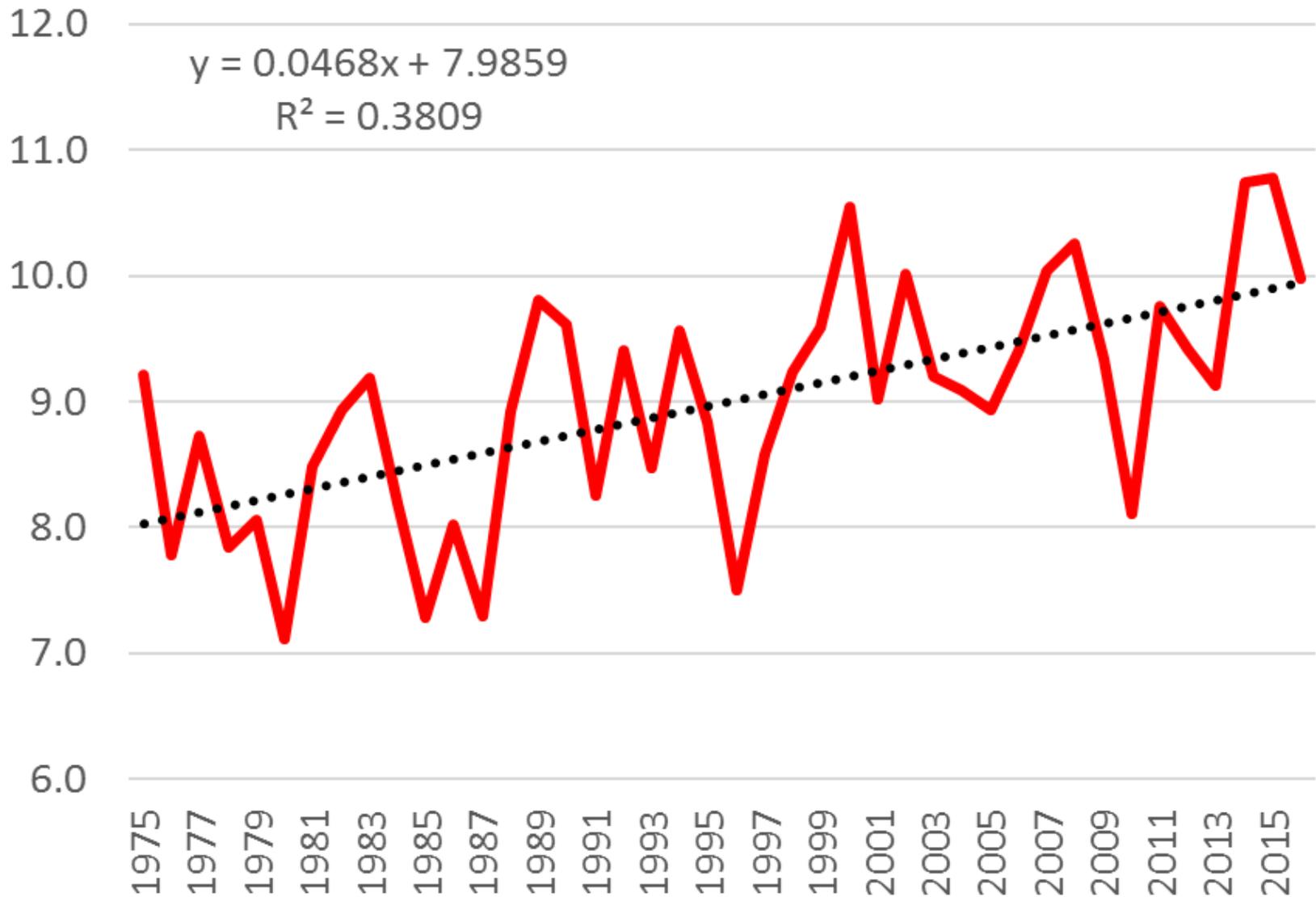


figure credit: National Center for Atmospheric Research, climatedataguide.ucar.edu (D. Schneider)

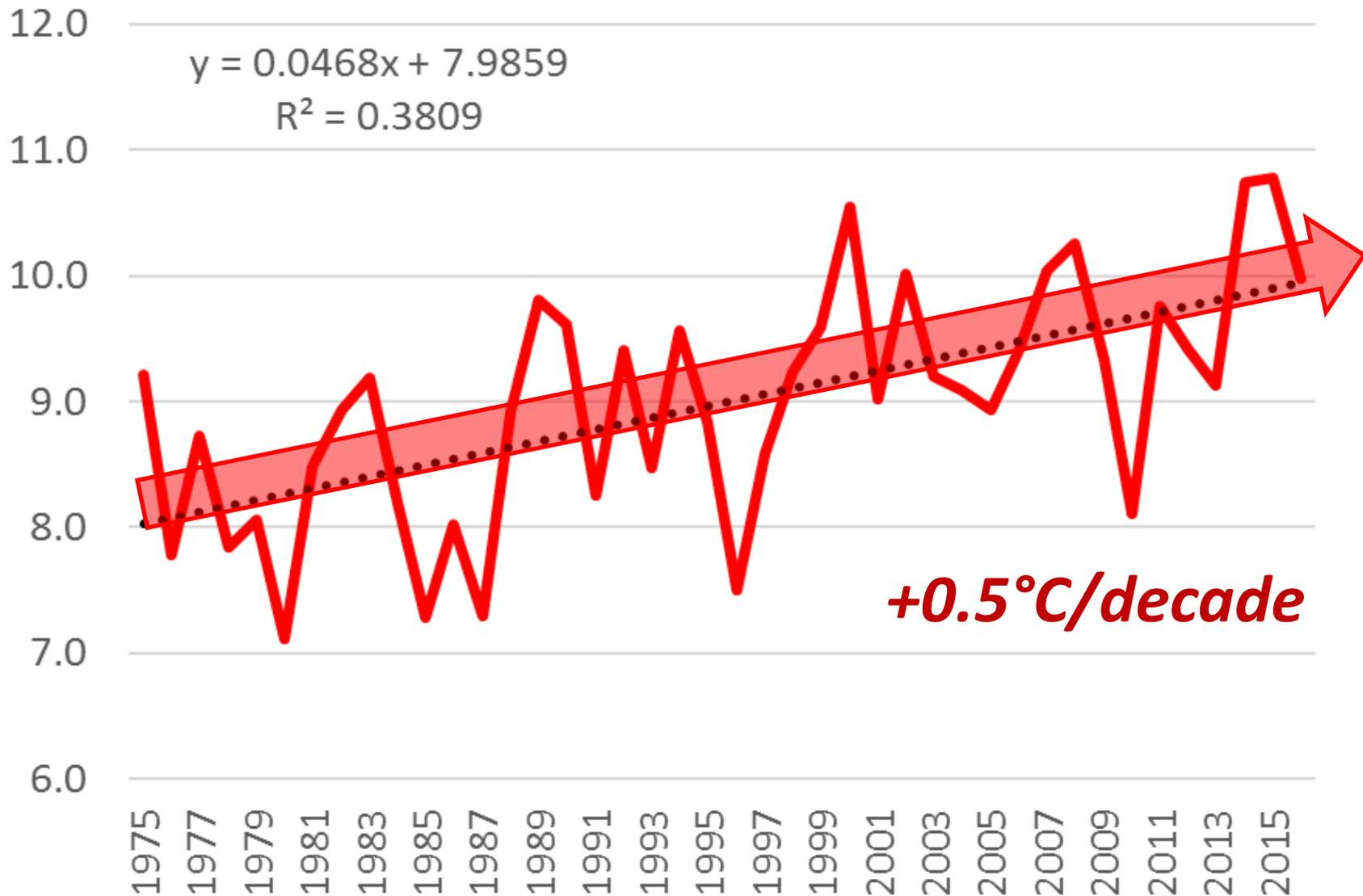


-2 -1.75 -1.5 -1.25 -1 -0.75 -0.5 -0.25 0 0.25 0.5 0.75 1 1.25 1.5 1.75 2

*Annual mean temperature in Poznań increased
by around 2.0°C*



Annual mean temperature in Poznań increased by around 2.0°C





**Climate
change**



**Pollen
seasons**



Start/End



Duration



Intensity

Climate change is a health threat

Rising temperatures lead to longer allergy seasons and can make air pollution worse. This can increase the risk and severity of asthma attacks and cause more allergies.



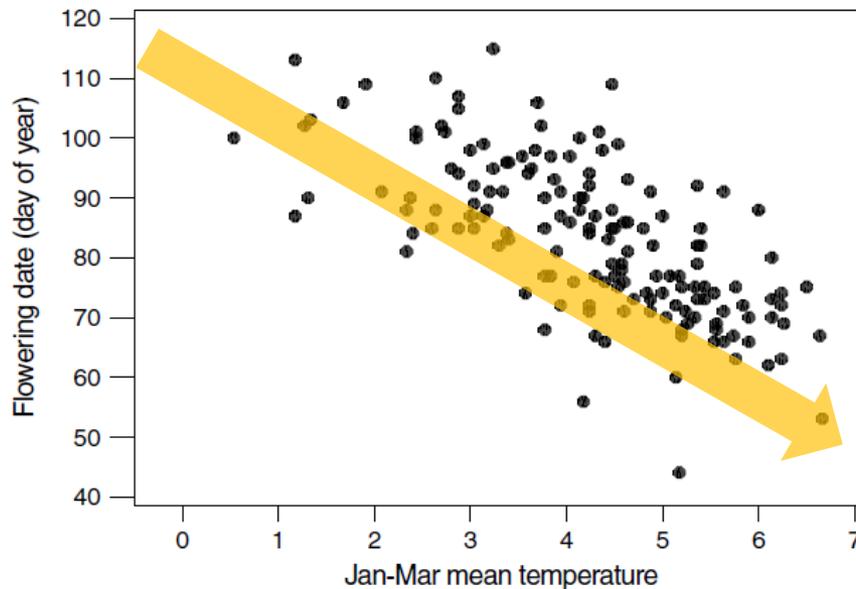
Asthma and Allergy
Foundation of America

Visit [AAFA.org](https://www.aaafa.org) to learn more.

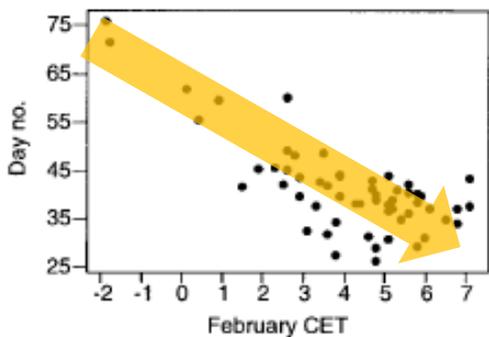
Effect of temperature on flowering



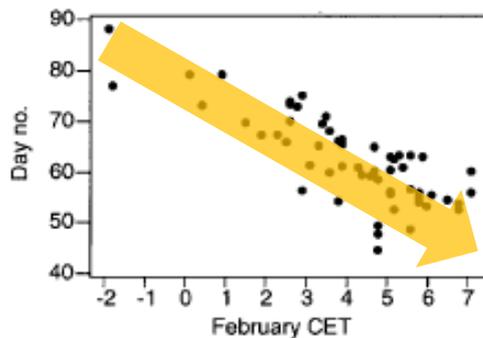
Anemone nemorosa



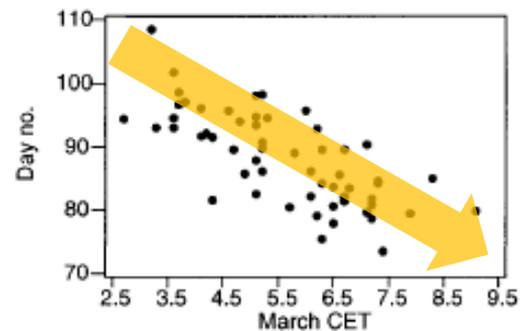
Hazel



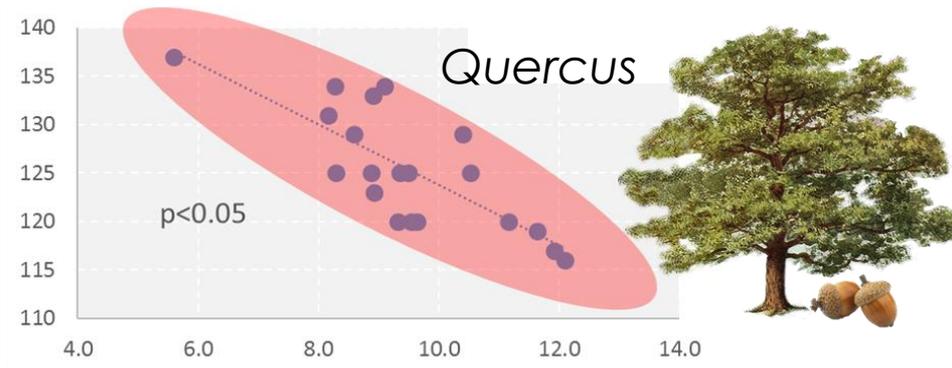
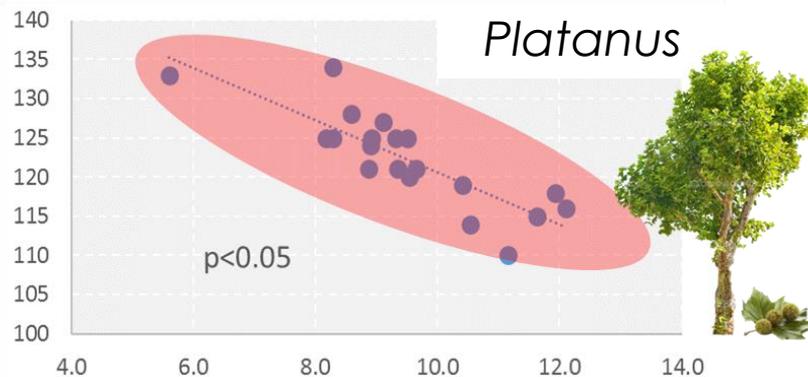
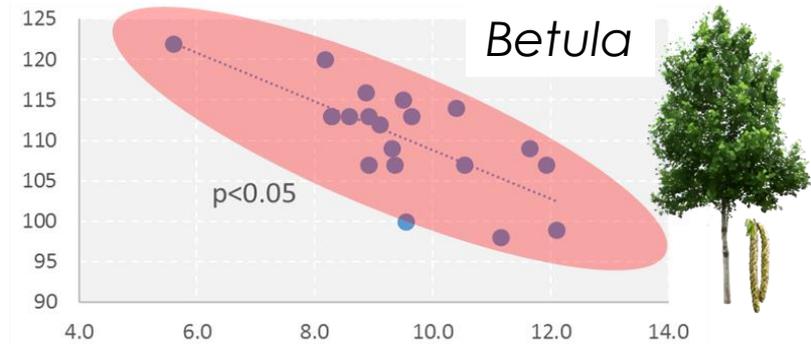
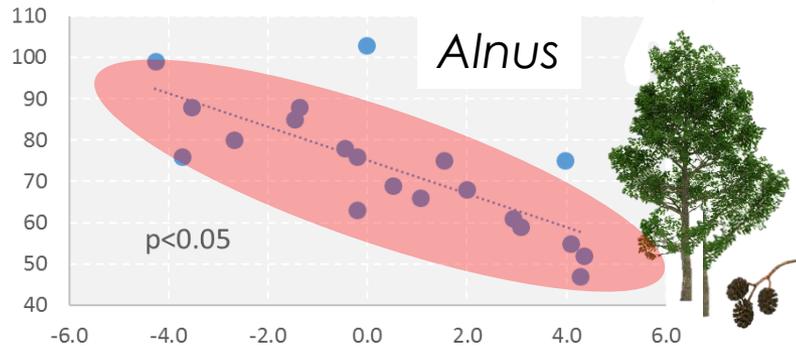
Coltsfoot



Wood anemone

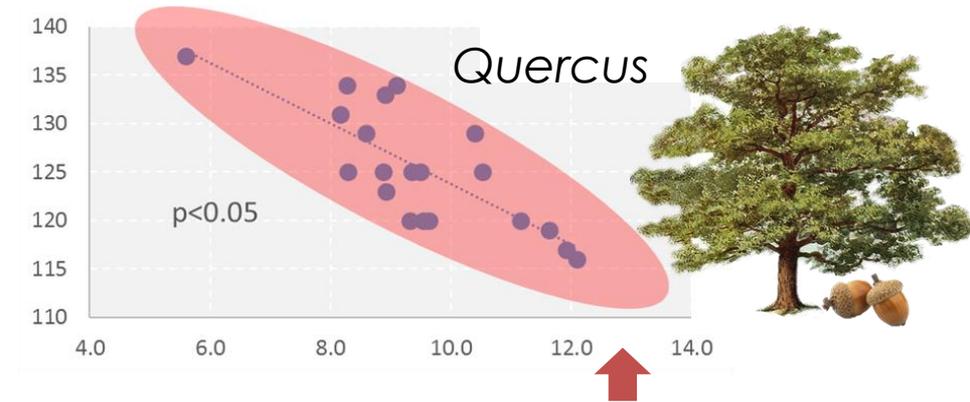
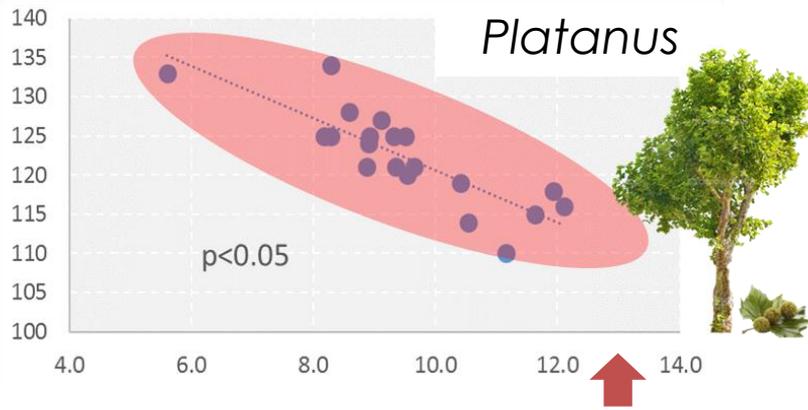
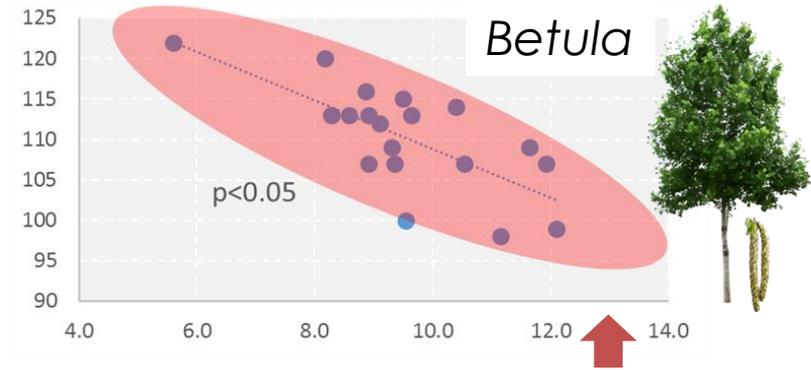
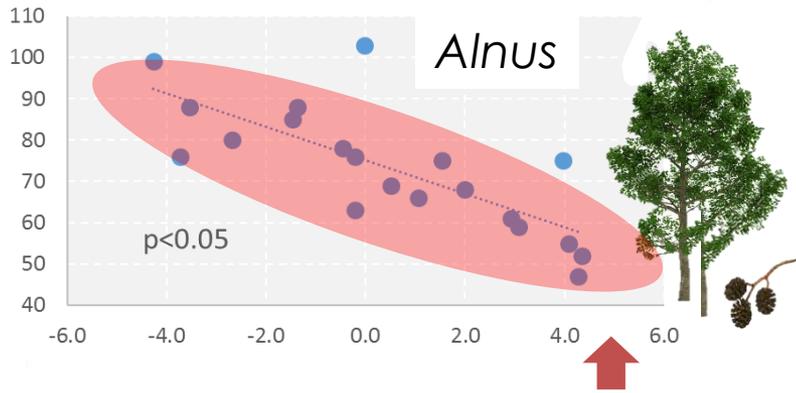


Pollination time depends on temperature recorded just before pollen release, i.e. few weeks



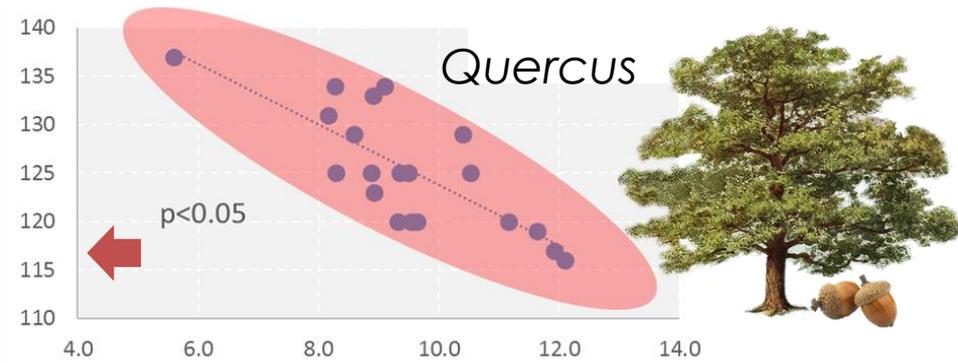
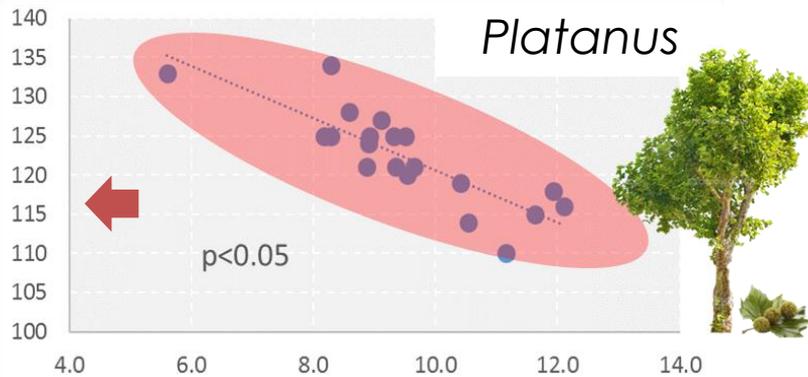
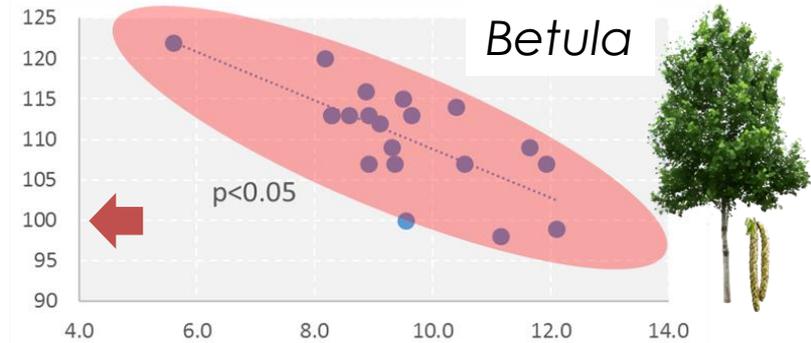
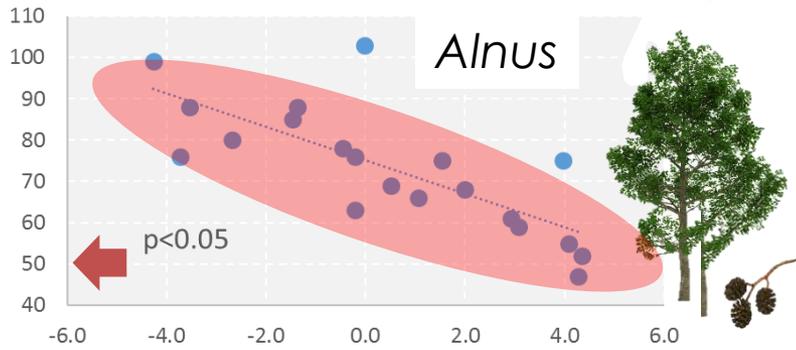
Mean monthly temperature

The higher temperature....



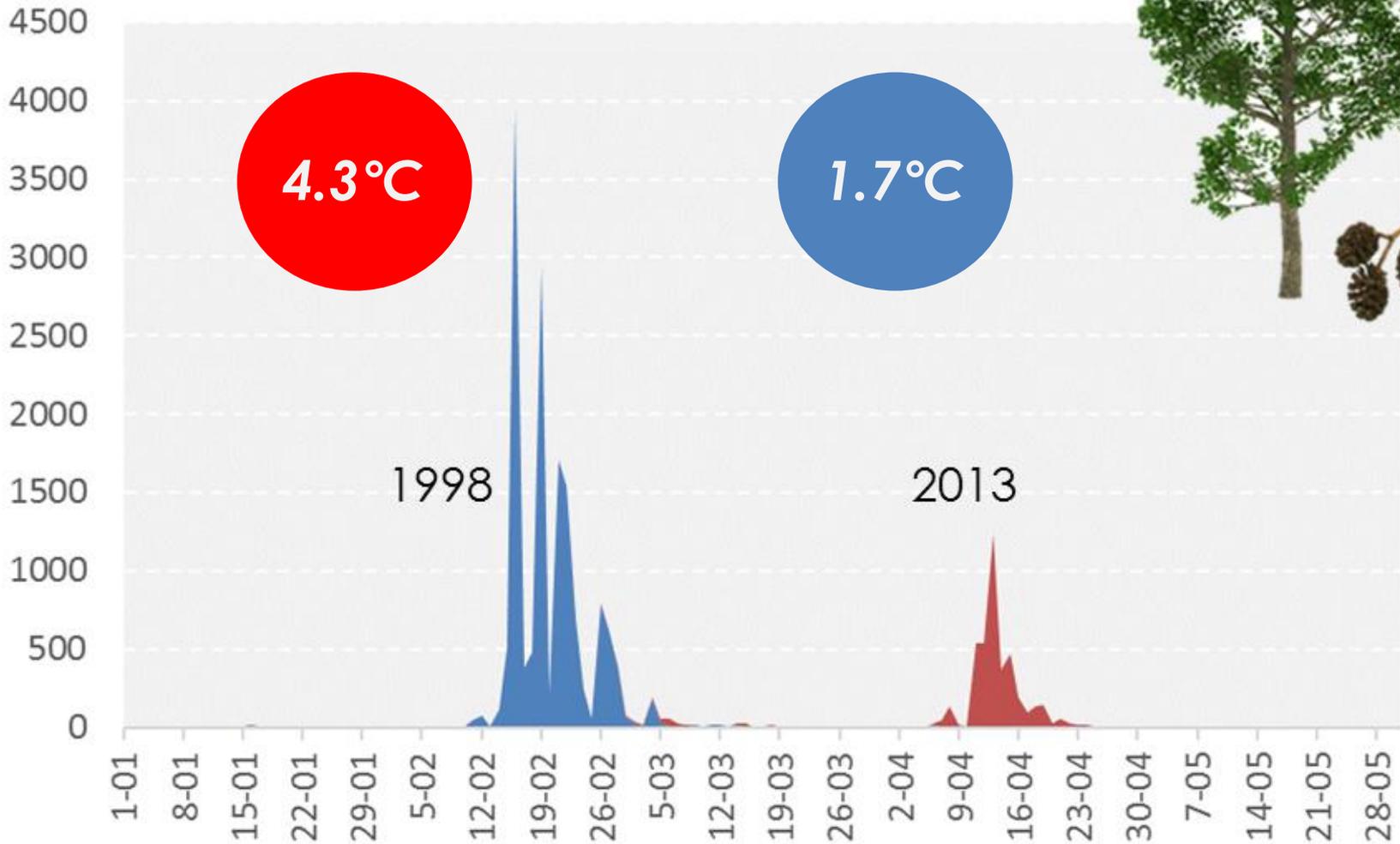
Mean monthly temperature

The higher temperature.... The earlier pollination



Mean monthly temperature

Variation in alder pollen season



Difference between the pollen season
start date

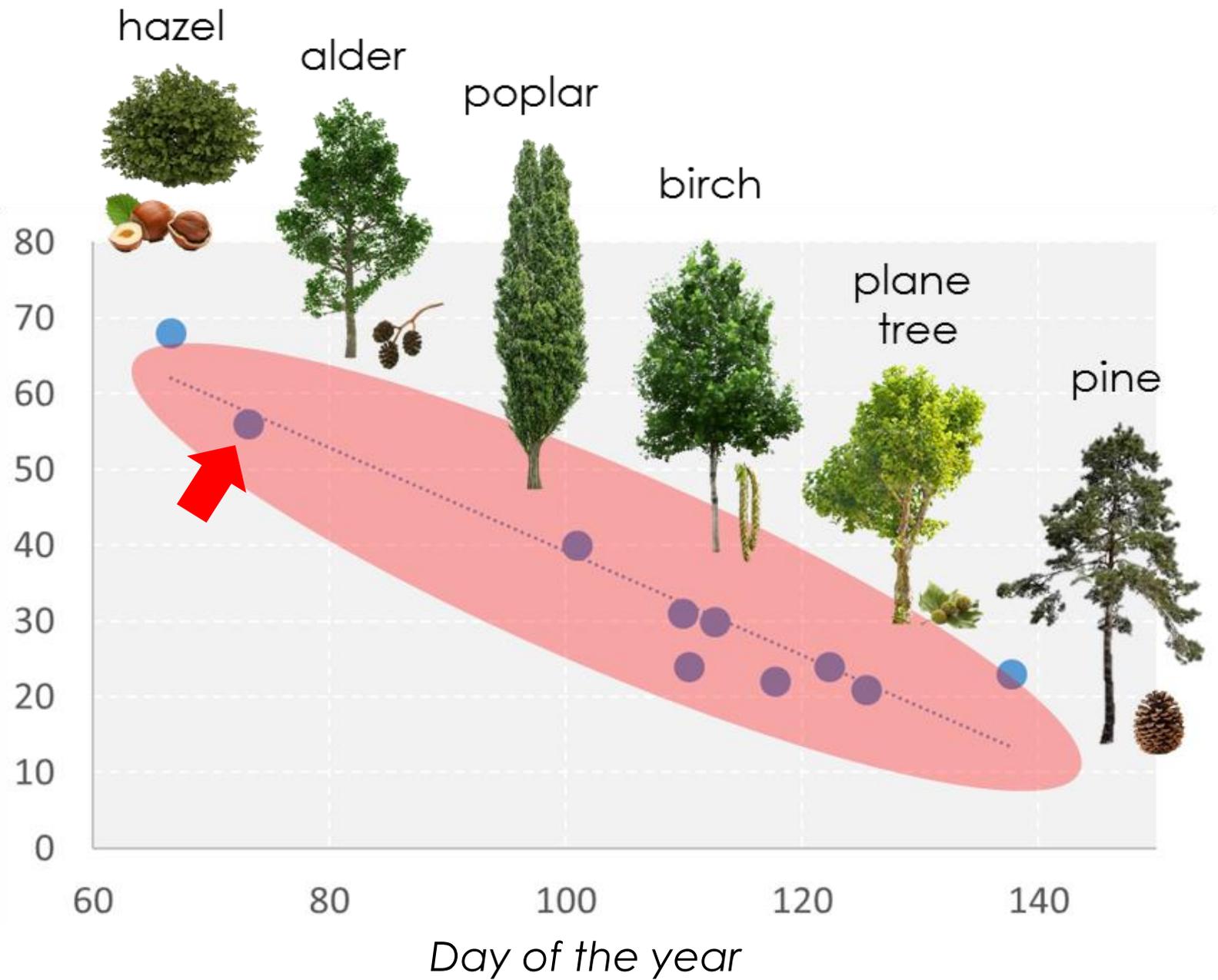


Table III. Change of commencement dates during the last 48 years for the eight studied calendars

No.	Site	Flowering of hazel	Flowering of colts-foot	Birch leaf unfolding	Flowering of apple		
1	Trier-Petrisberg	-0.40	-0.12	-0.03	0.01	0.07	-0.04

Europe

Table 2 Summary of full bloom dates and trends for apple and pear cultivars: 1973–2009.

Cultivar	Mean (full bloom date)	SD (days)	Earliest (full bloom)	Latest (full bloom)	Slope	P
<i>Malus domestica</i>						
Golden Delicious	19-October	5.69	9/10/1995	29/10/1974	-1.9'	0.027
Sayaka	19-October	5.21	7/10/2009	31/10/2009	-1.4'	0.075
Granny Smith	18-October	4.35	8/10/1995	26/10/1978	-1.1'	0.096
						0.077
						0.096

Africa

Table 2 Mean and temporal change of budding and flowering dates

Location	Budding date				Flowering date			
	Mean	Trend (day yr ⁻¹)	r	τ	Mean	Trend (day yr ⁻¹)	r	τ
A	April 9	-0.23 (0.12)	-0.34 ⁺	-0.21	May 9	-0.24 (0.14)	-0.31	-0.23 ⁺

Asia

ONSET OF NH SPRING

R 345

America

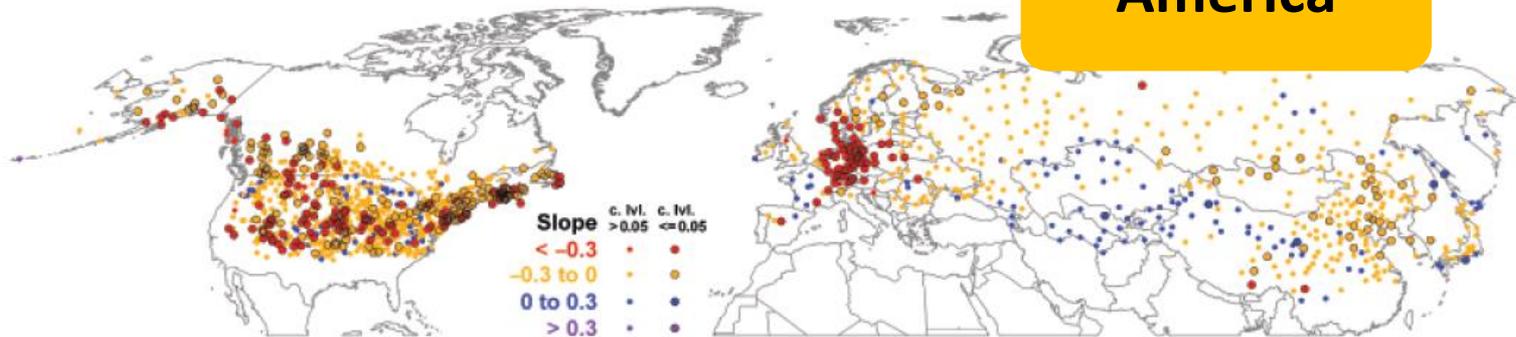


Fig. 1 Spring indices (SI) first leaf date 1961–2000 trend by station. Trend values are in days per year and colors show categories. Stations with trends significant at the 0.05 level or better are shown with larger symbols outlined in black.

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Table 2 Mean and temporal change of budding and flowering dates

Location	B	(-1)	τ
A			0.31 -0.23+ 0.26+ 0.33* 0.36** 0.26+ 0.19

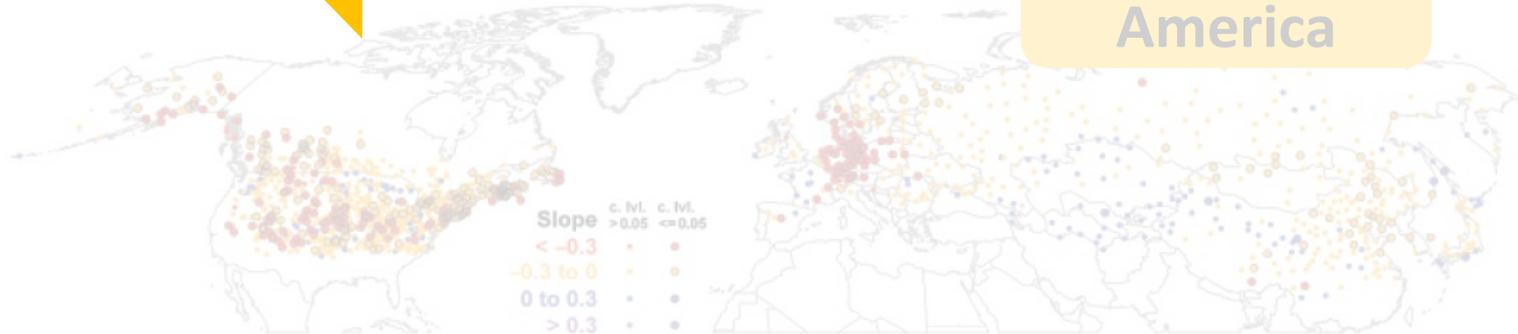
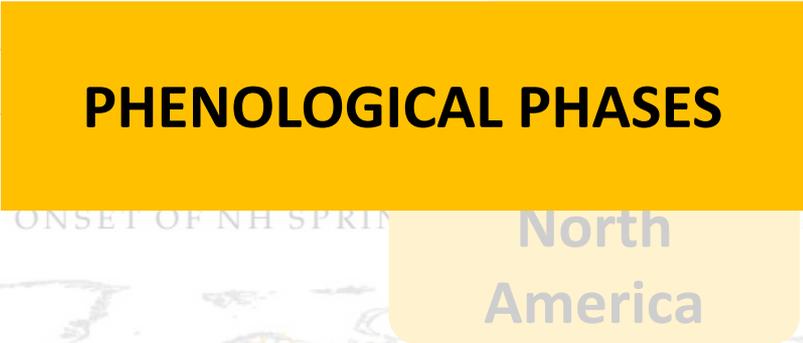


Fig. 1 Spring indices (SI) first leaf date 1961–2000 trend by station. Trend values are in days per year and colors show categories. Stations with trends significant at the 0.05 level or better are shown with larger symbols outlined in black.

Interactions between climatic changes and allergenic plants



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Atmospheric Environment 41 (2007) 7011-7021

ATMOSPHERIC ENVIRONMENT

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Long-term trends in atmospheric pollen levels in the city of

Frenquelli

DOI: 10.1002/joc.820

AND CLIMATE CHANGE ON THE TIMING OF POLLEN RELEASE IN THE NETHERLANDS

ARNOLD J. H. VAN VLIET,^{1*} AART OVEREEM,^{1*} RUDOLF S. DE GROOT,² ADRIE F. G. JACOBS³ and FRITS T. M. SPIEKMA²

part of the concentration

of the most important allergenic pollens?

UWE KAMINSKI^{1*} and TOM GLOD²

¹German Meteorological Service, Centre for Human Biometeorological Research, Freiburg, Germany
²University of Trier, FB Physical Geography, Trier, Germany

and Italy

EMMA TEDESCHINI¹, F. JAVIER RODRIGUEZ-RAJO², ROSANNA CARAMIELLO³, VICTORIA JATO² & GIUSEPPE FRENGUELLI¹

¹Department of Plant Biology and Agroenvironmental Biotechnology and Animal Production, University of Perugia, Perugia, Italy; ²Department of Plant Biology and Soil Sciences, Campus Ar Lagoas, University of Vigo, Ourense, Spain, and ³Department of Plant Biology, University of Torino, Torino, Italy.

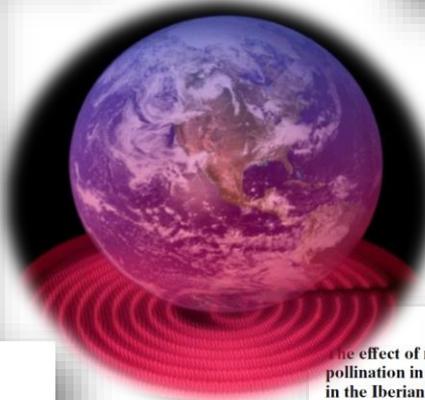
General Trends in Airborne Pollen Production and Pollination Periods at a Mediterranean Site (Badajoz, Southwest Spain)

R Tormo-Molina,¹ MA Gonzalo-Garjito,² I Silva-Palacios,³ AF Muñoz-Rodríguez²

The effects of climate change in Switzerland 1969-1996 on airborne pollen quantities from hazel, birch and grass

Thomas Diez

* Swiss Meteorological Institute, Zurich, Switzerland



Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Phenological trends in southern Spain: A response to climate change

H. García-Mozo^{a,*}, A. Mestre^b, C. Galán^a

Data contributors¹

Vol. 48: 281-291, 2011
doi:10.3334/cr00966

CLIMATE RESEARCH
Clim Res

Published August 30

Contribution to CR Special 27 'Climate change in the NW Iberian Peninsula'



Recent trends in airborne pollen for tree species in Galicia, NW Spain

F. J. Rodríguez-Rajo^{1,*}, M. J. Alra², M. Fernández-González¹, C. Seijo¹, V. Jato¹

ACTA CLIMATOLOGICA ET CHOROLOGICA
Universitatis Szegediensis, Tomus 44-45, 2011, 111-125

TRENDS IN THE CHARACTERISTICS OF ALLERGENIC POLLEN

Aerobiologia 19: 227-234, 2003.



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L. MAR

¹Department of Climatology and Landsc

²Department of Meteorology, Eötvös

Trends in airborne pollen: A (Switzerland)

Bernard Clot
Laboratoire de botanique évolutive de l'Un
Switzerland
(Fax: +41 26 662 62 12; E-mail: bernard.cl



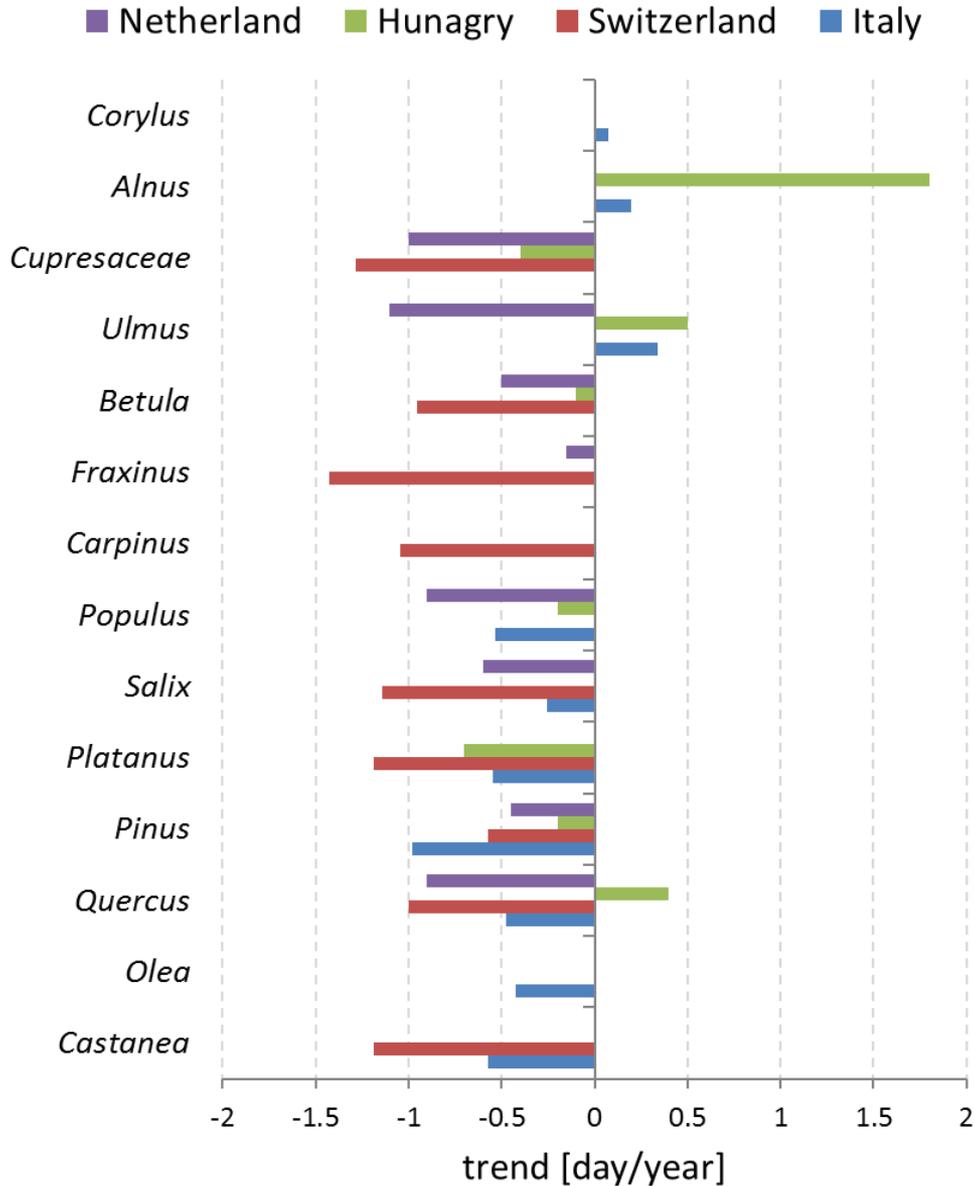
Grana

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/sgra20>

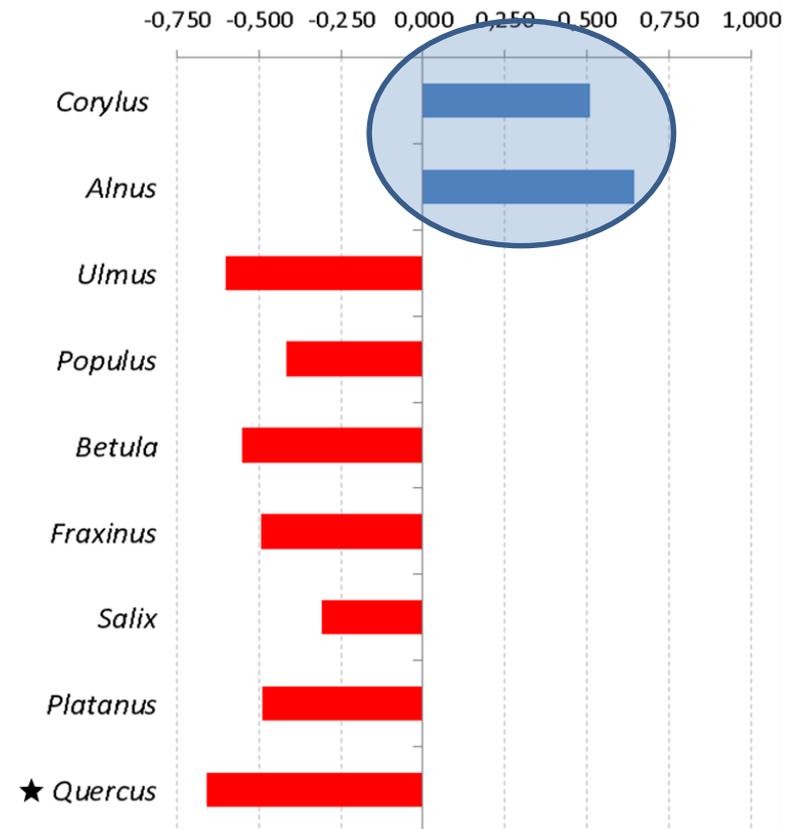
Altering airborne pollen concentrations due to the Global Warming. A comparative analysis of airborne pollen records from Innsbruck and Obergurgl (Austria) for the period 1980-2001

The pollen seasons start earlier

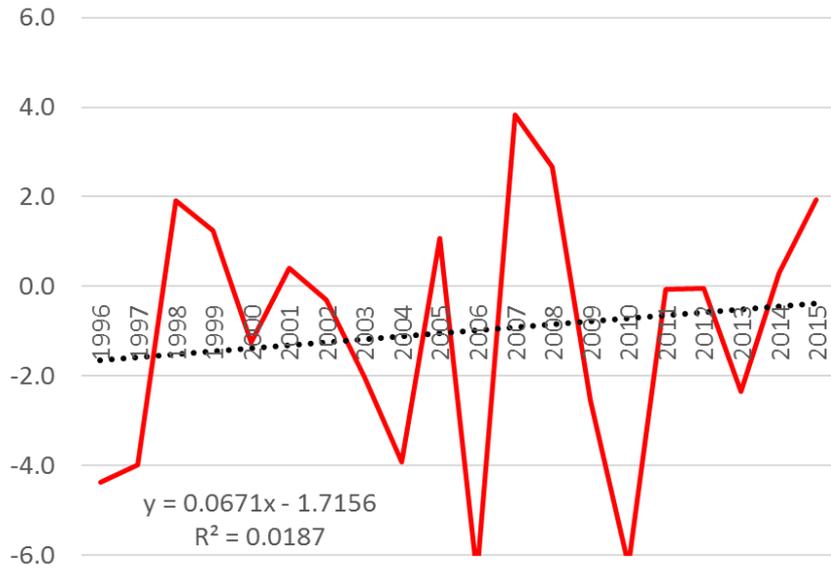


Poznań

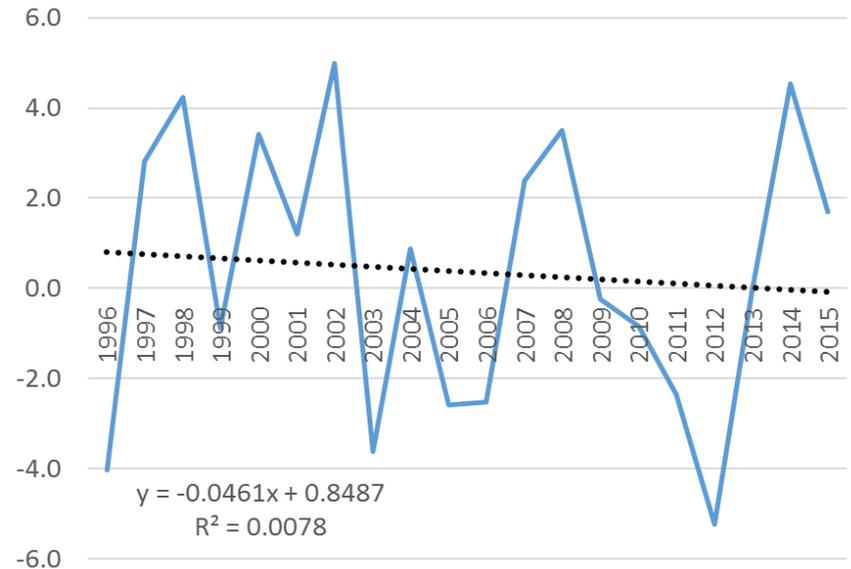
Slope of the trend



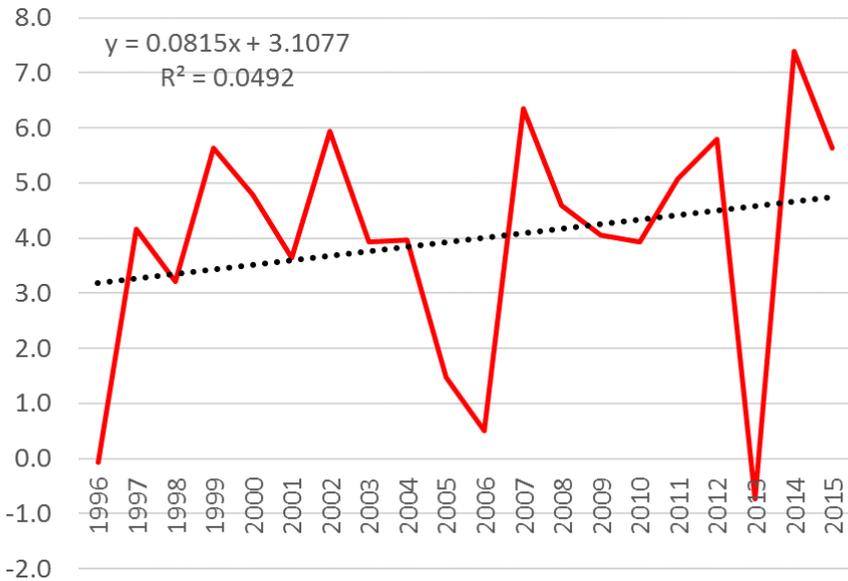
January



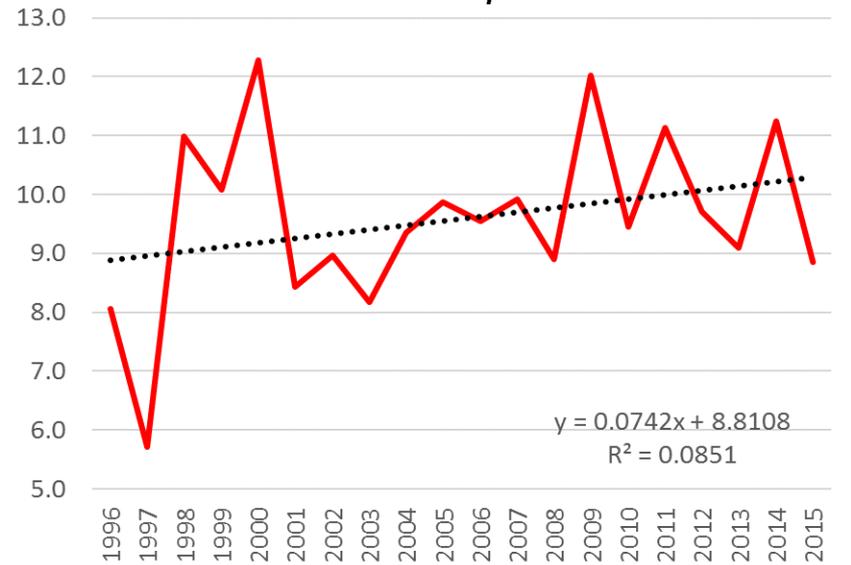
February



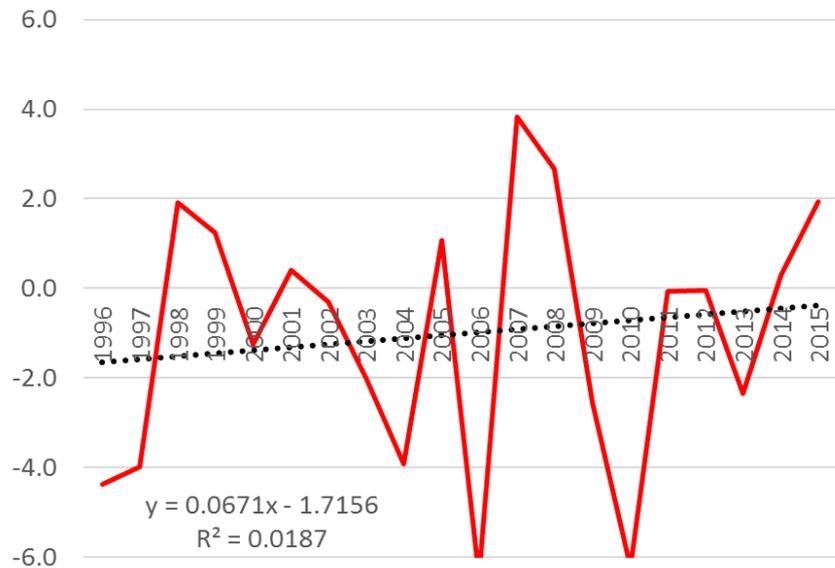
March



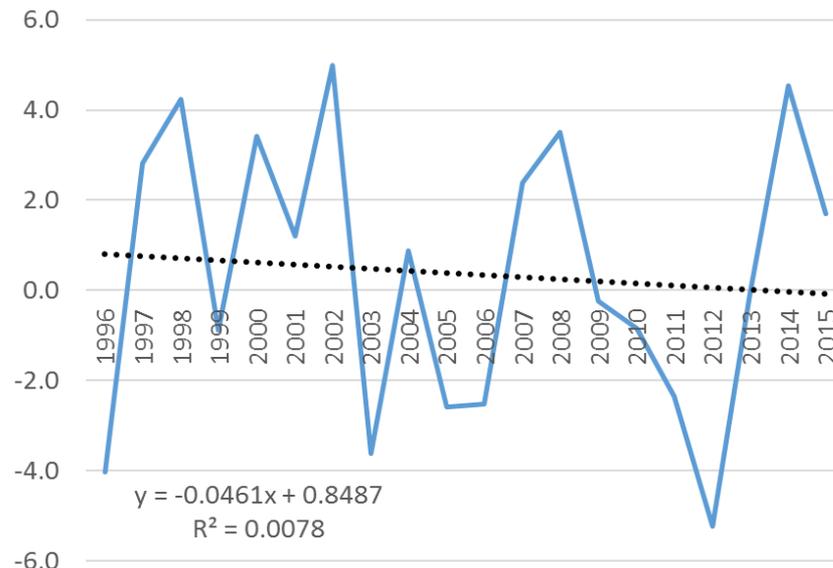
April



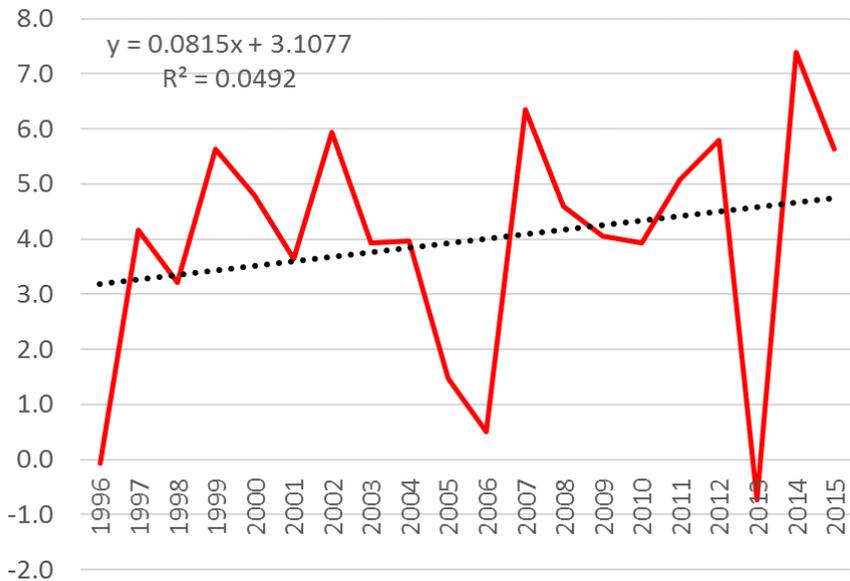
January $+0.07^{\circ}\text{C}/\text{year}$



February $-0.05^{\circ}\text{C}/\text{year}$



March $+0.08^{\circ}\text{C}/\text{year}$



April $+0.07^{\circ}\text{C}/\text{year}$

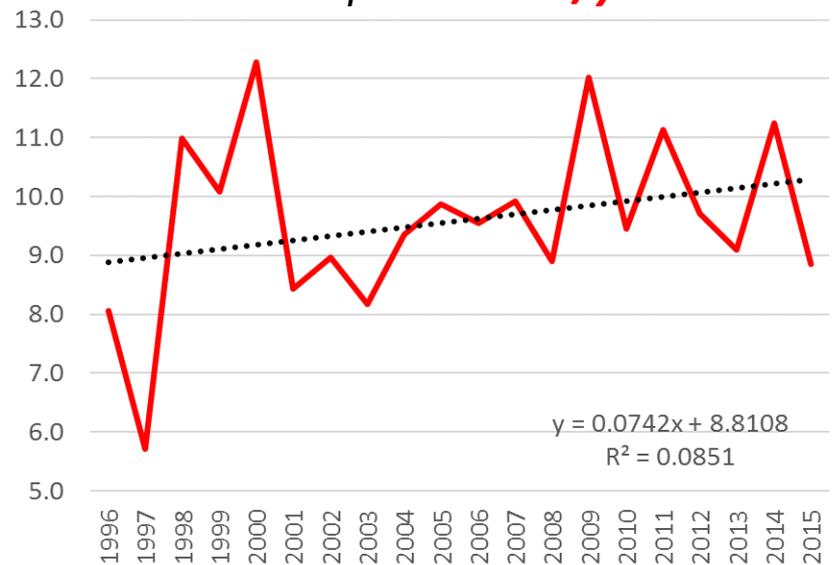


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Africa

Table 2 Mean and temporal change of budding and flowering dates

Location	B	(-1)	τ
A			0.31
			-0.23+
			0.26+
			0.33*
			0.36**
			0.26+
			0.19



START OF POLLEN SEASON OF TREES

North America

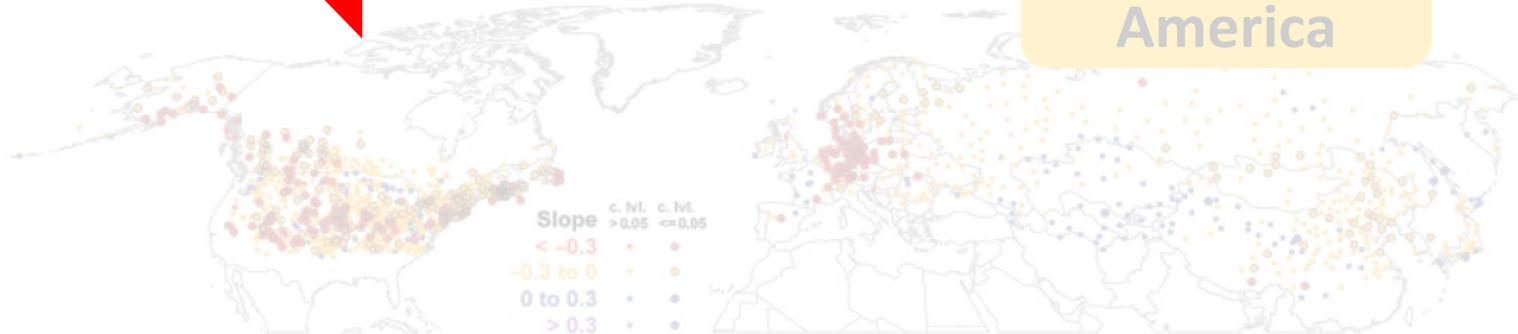
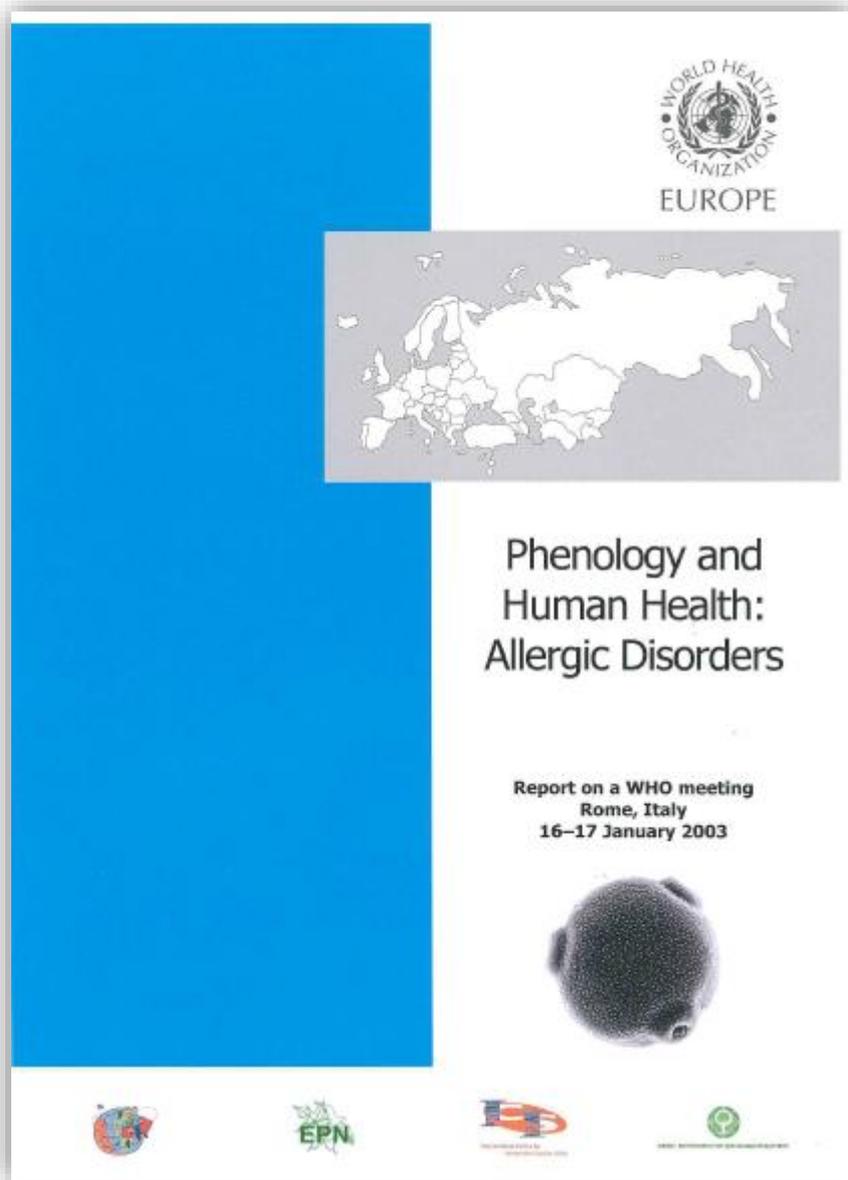
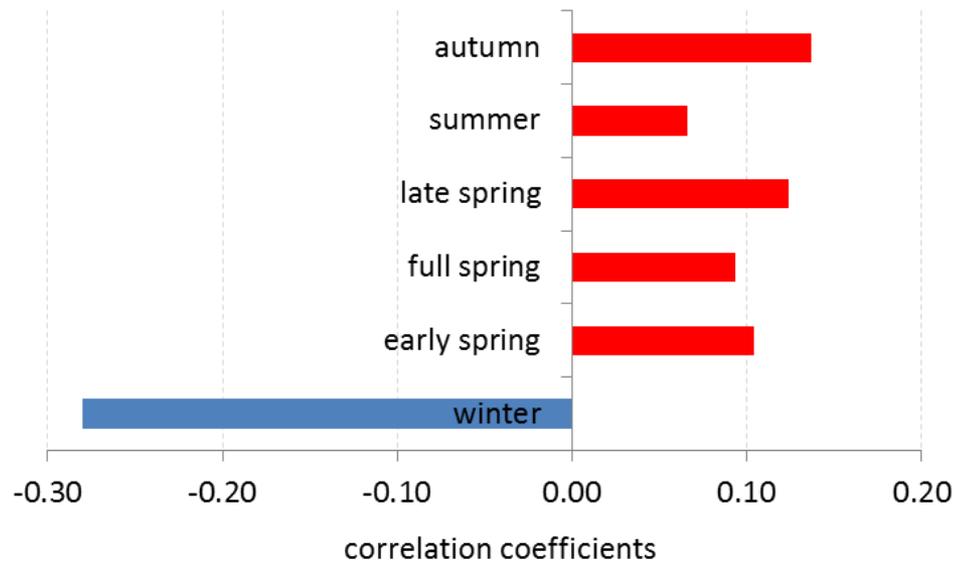


Fig. 1 Spring indices (SI) first leaf date 1961–2000 trend by station. Trend values are in days per year and colors show categories. Stations with trends significant at the 0.05 level or better are shown with larger symbols outlined in black.

What about the duration of pollen season?



Changes in start and duration of pollen season in Europe, 1974-2002 (Jäger 2001).



„Warming is likely to further cause an earlier onset and may **extend the duration of flowering and pollen season**, for some species (e.g. grasses, weeds).”

REVIEW

Impacts of climate change on aeroallergens: past and future

P. J. Begg

Department of Physical Geography, Division of Environmental and Life Sciences, Macquarie University, NSW 2109, Australia

Summary
carbon dioxide
concentration
has increased
considerably
in recent years
and is expected
to continue to
increase in the
future. This
review examines
the impact of
climate change
on aeroallergens
and discusses
the potential
impacts of
climate change
on aeroallergens
in the future.

REVIEW

Effects of climate change on environmental factors in respiratory allergic diseases

G. D'Amato* and L. Cecchi†,‡

*Division of Respiratory and Allergic Diseases, Department of Chest Diseases, Federico II University of Naples, Naples, Italy and †Allergy Clinic, A...

Keywords
temperature
precipitation

Clinical and Experimental Allergy

Summary
A body of evidence suggests that global warming is affecting human environment. This includes a direct effect of a warmer atmosphere on the concentration of gaseous and particulate air pollutants and the impact of climate change on the distribution of allergenic plants. This review suggests that air pollution is used to study the interrelationship between climate change and respiratory allergy. In conclusion, climate change is expected to increase the prevalence of allergic diseases in biological and chemical pollution, air pollution. In conclusion, climate change is expected to increase the prevalence of allergic diseases in biological and chemical pollution, air pollution.

Correspondence: Prof. Gennaro D'Amato, Division of Respiratory and Allergic Diseases, Department of Chest Diseases, High Specialty Hospital 'A. Cardarelli', Naples, Italy. E-mail: gdamato@pubb.unife.it

Introduction

It is now widely accepted that the earth's temperature is increasing, as confirmed by the warming of the sea rising sea levels, melting glaciers, retreating sea ice in Arctic and diminished snow cover in the Northern Hemisphere. Moreover, changes are also occurring in amount, intensity, frequency and type of precipitation well as the increase of extreme events, like heat waves, droughts, floods and hurricanes. As stated in the Intergovernmental Panel on Climate Change (IPCC), 'most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations' [1].

REVIEW ARTICLE

Projections of the effects of climate change on allergic asthma: the contribution of aerobiology

L. Cecchi†*, G. D'Amato‡, J. G. Ayres§, C. Galan¶, F. Forastiere¶, B. Forsberg¶, J. Gerritsen¶, C. Nunes¶, H. Behrend¶, C. Akdis¶, R. Dahl¶ & L. Annesi¶

†Interdepartmental Centre of Biostatistics, University of Florence, Florence, Italy; ‡Division of Chest Diseases, High Specialty Hospital 'A. Cardarelli', Naples, Italy; §Institute of Birmingham, Birmingham, UK; ¶Department of Plant Biology, University of Cordoba, Spain; ¶Centre for Environmental and Occupational Medicine, Umeå University, Sweden; ¶Centre for Allergy, University of Groningen, the Netherlands; ¶Centre for Immunology, Dermatology and Allergy (CIMA), University of Munich, Munich, Germany; ¶Swiss Institute of Allergy and Asthma Research (SIAS), University of Zurich, Zurich, Switzerland; ¶Department of Respiratory Diseases, Aarhus University Hospital, Aarhus University Hospital, Aarhus, Denmark; ¶Allergy Unit, University of Paris, Paris, France

To view this article: Cecchi L, D'Amato G, Ayres JG, Galan C, Forastiere F, Forsberg B, Gerritsen J, Nunes C, Behrend H, Akdis C, Dahl R, Annesi L. Projections of the effects of climate change on allergic asthma: the contribution of aerobiology. Allergy 2014; 69: 1507–1513.

Keywords

allergic diseases; climate change; environment; pollen; spores.

Correspondence

L. Cecchi, Interdepartmental Centre of Biostatistics, University of Florence, Piazza dei Cavalotti 18, 50144 Florence, Italy. Tel: +39 055 2389257 Fax: +39 055 2324472 E-mail: lower.cecchi@unife.it

*EAAC/ERS Task Force on 'Effects of Climate change on respiratory allergic diseases and on asthma prevalence'

Accepted for publication 9 May 2014

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There is unequivocal evidence that the climate is changing and at an increasing rate. Global average temperature has increased by more than 0.7°C over the past 100 years, and the Intergovernmental Panel on Climate Change (IPCC) projects that the average global surface air temperature in the years 2090–2099 are likely to be between 1.8 and 4.0°C warmer than those in 1980–1999, depending on which climate scenario is input into the models [1]. In addition to global warming, some regions, including northern Europe, are projected to experience increased rainfall while others, including the Mediterranean, are expected to experience substantial droughts. Extreme weather events, such as heat waves, heavy precipitation and

thunderstorms are also expected to increase in frequency and intensity. This is likely to have a significant impact on the distribution of allergenic plants and fungi and on the prevalence of allergic diseases. In conclusion, climate change is expected to increase the prevalence of allergic diseases in biological and chemical pollution, air pollution.

Global climate change is likely to have had, and to have, impacts on human health. While not received increasing attention in recent years, climate change on aeroallergens and asthma have been somewhat neglected. Despite this, studies have revealed potential impacts of climate change on aeroallergens that may have enormous clinical significance.

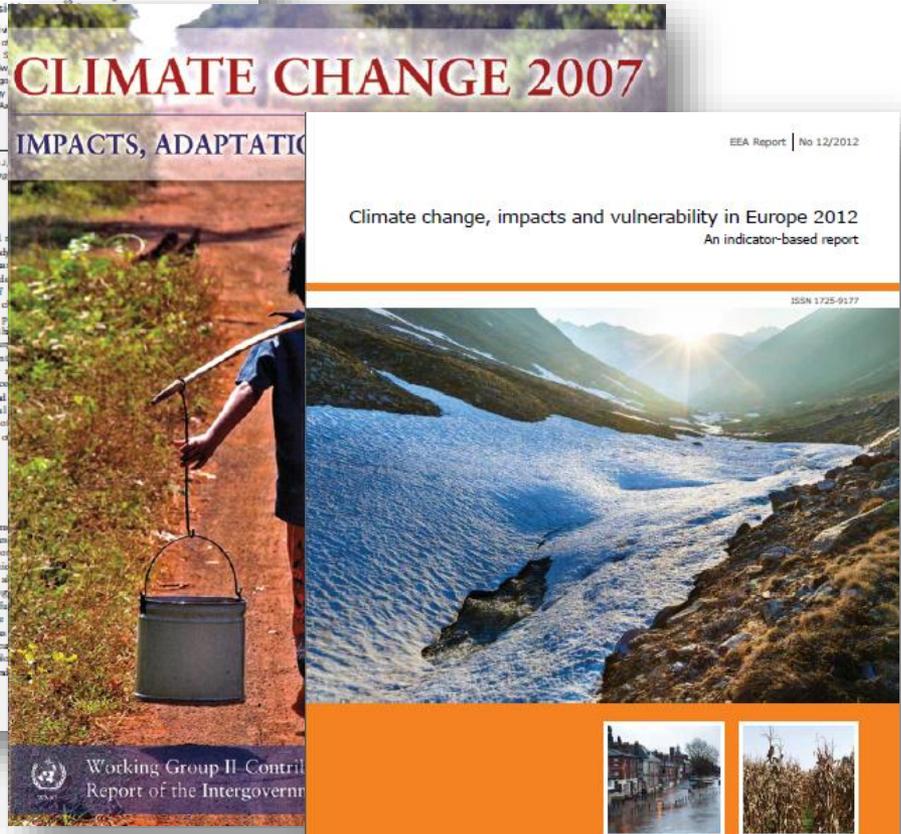
Human activities have resulted in increases in atmospheric greenhouse gases in global climate. Before the Industrial Era (the pre-18th century), atmospheric CO2 concentration was 280 ± 10 ppm. In several thousand years (since then, with the most annual concentration in 2012 at 371.10 ppm [2]). The best estimate of average surface temperature change is 0.8°C (the late 19th century, with a 95% confidence interval of 0.5°C [3]).

The Special Report on Emissions Scenarios produced a series of scenarios of CO2, emissions outcomes of distinct narratives of economic de-

Correspondence: Prof. John Begg, Department of Physical Geography, Division of Environmental and Life Sciences, Macquarie University, NSW 2109, Australia. Email: john.begg@mq.edu.au

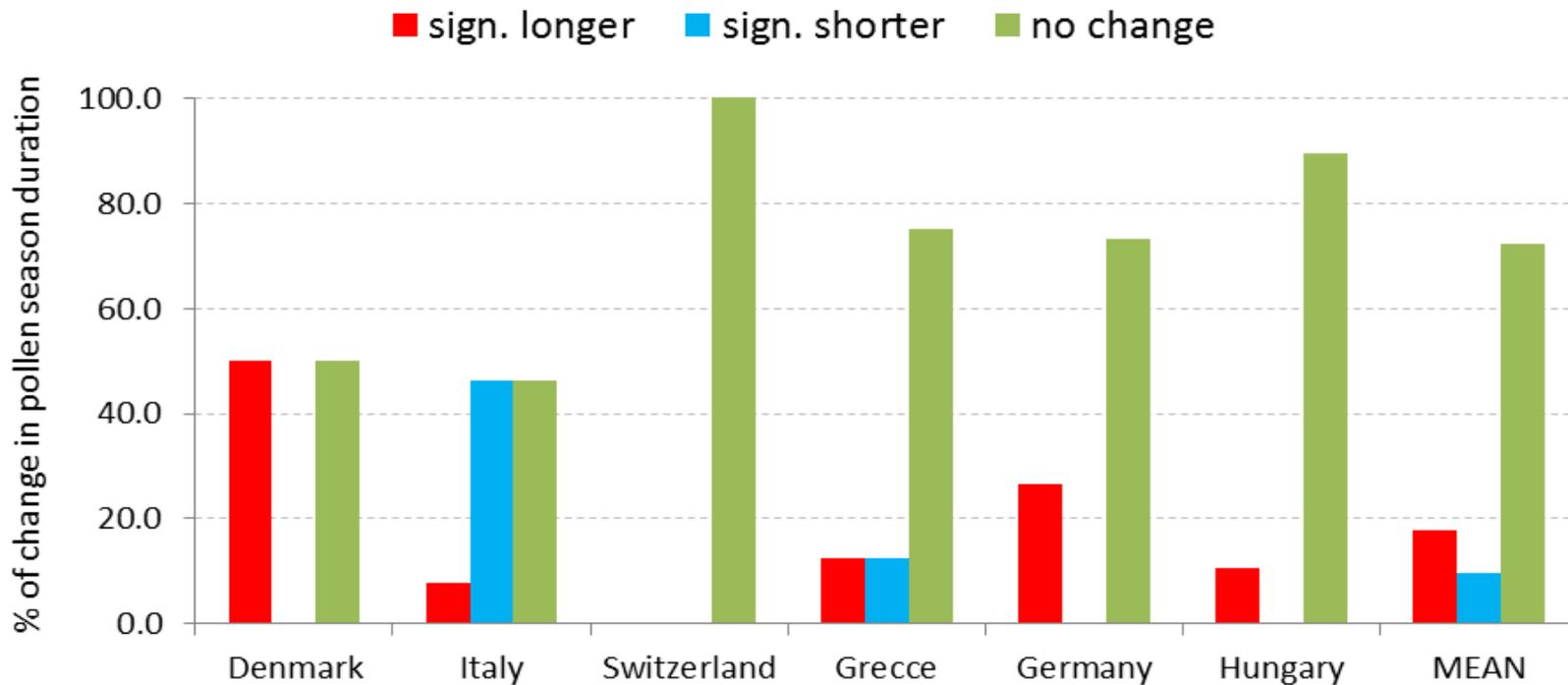
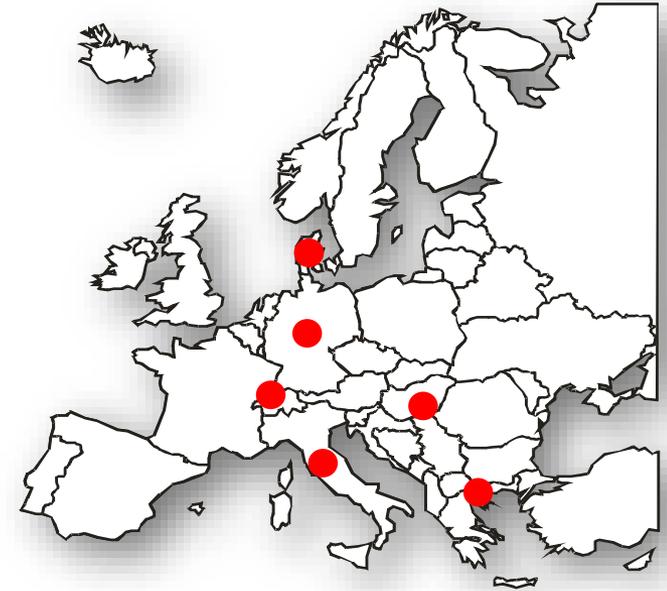
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„The pollen season is longer“.



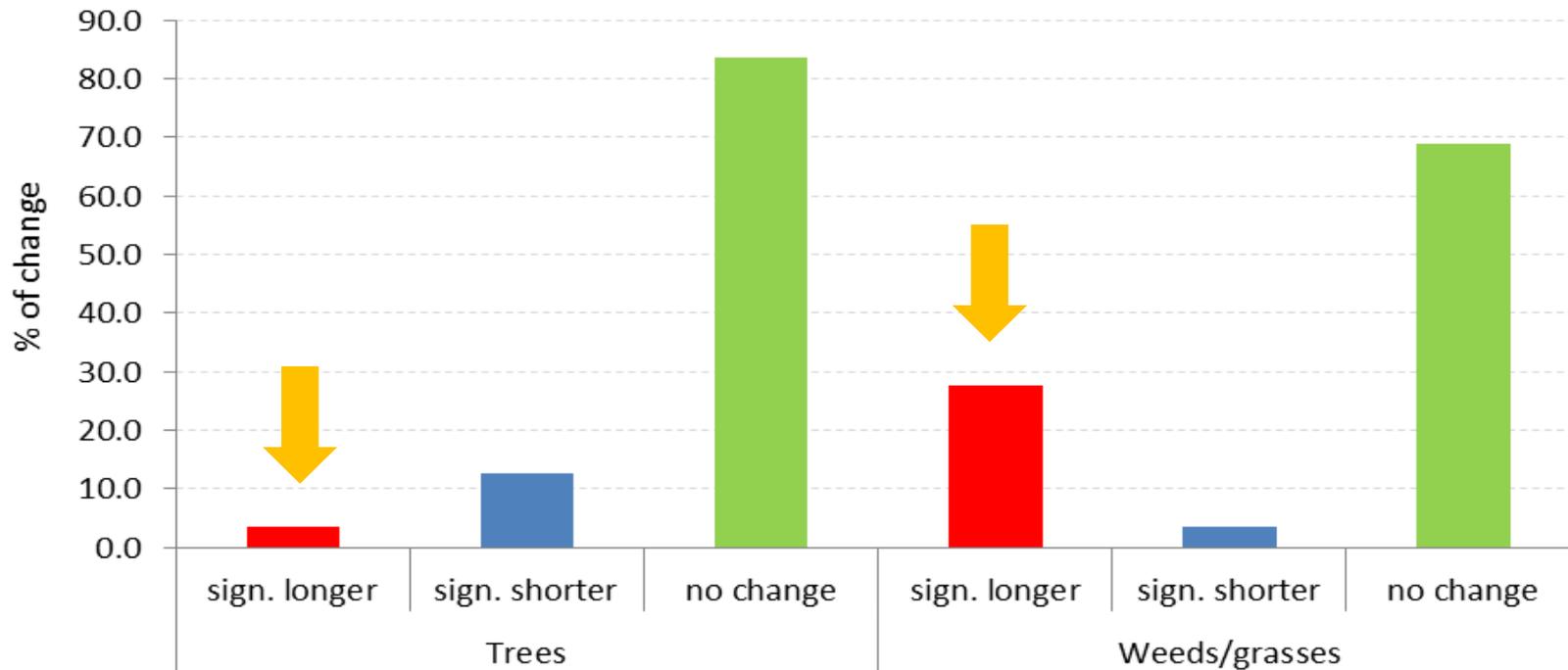
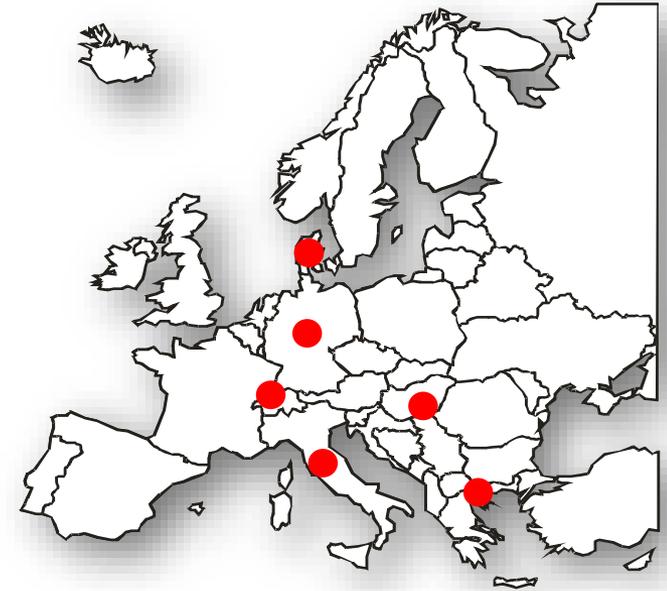
Duration of pollen season

Country	Number of data series	Length of data series	References
Denmark	2	1979-1998	Rasmussen (2002)
Italy	13	1982-2001	Frenguelli (2002)
Switzerland	19	1979-1999	Clot (2003)
Grecce	16	1987-2005	Damialis et al. (2007)
Germany	15	1994-2009	Kaminski (2011)
Hungary	19	1997-2007	Marka et al. (2011)

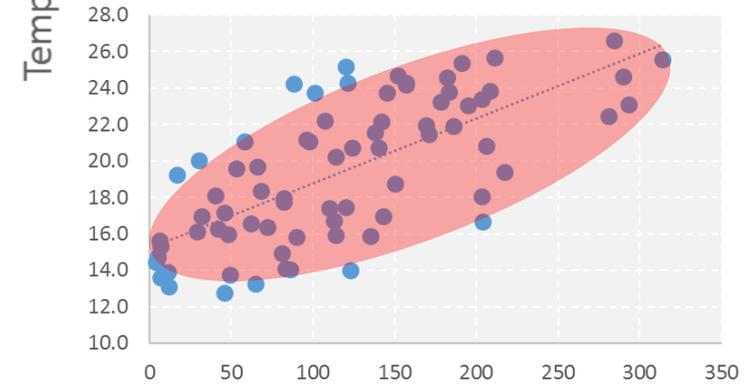
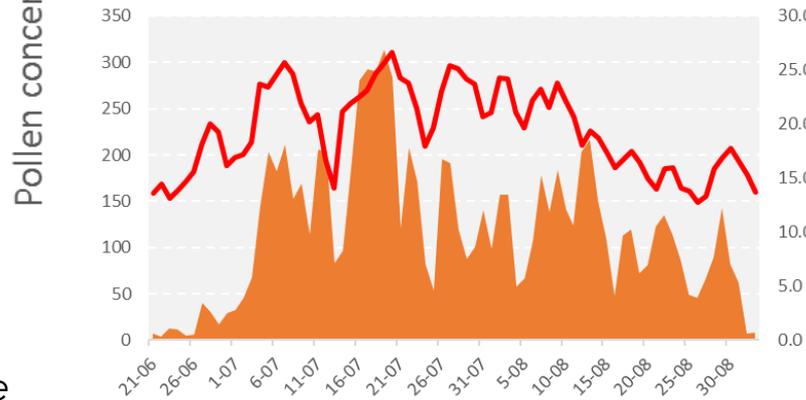
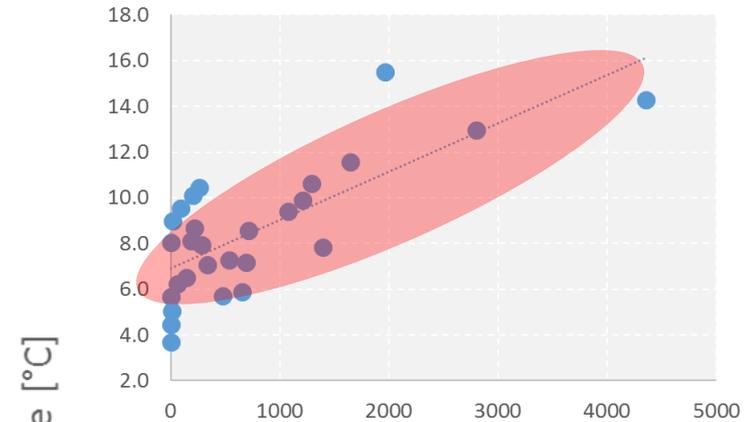
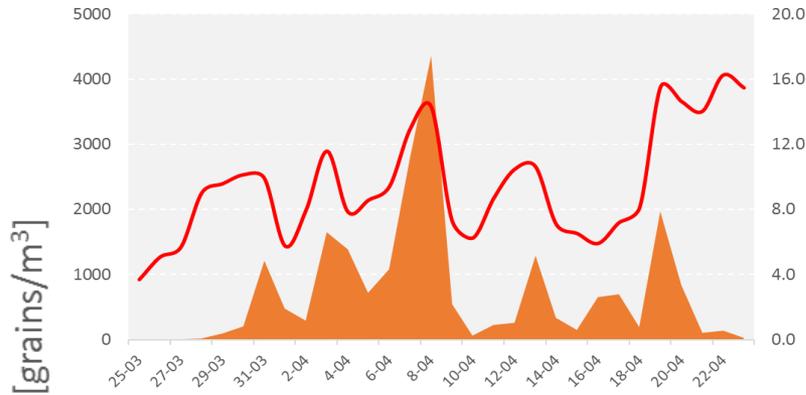
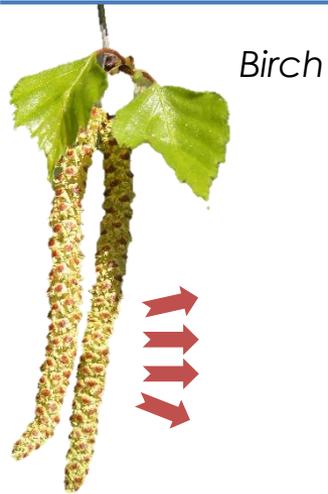


Duration of pollen season

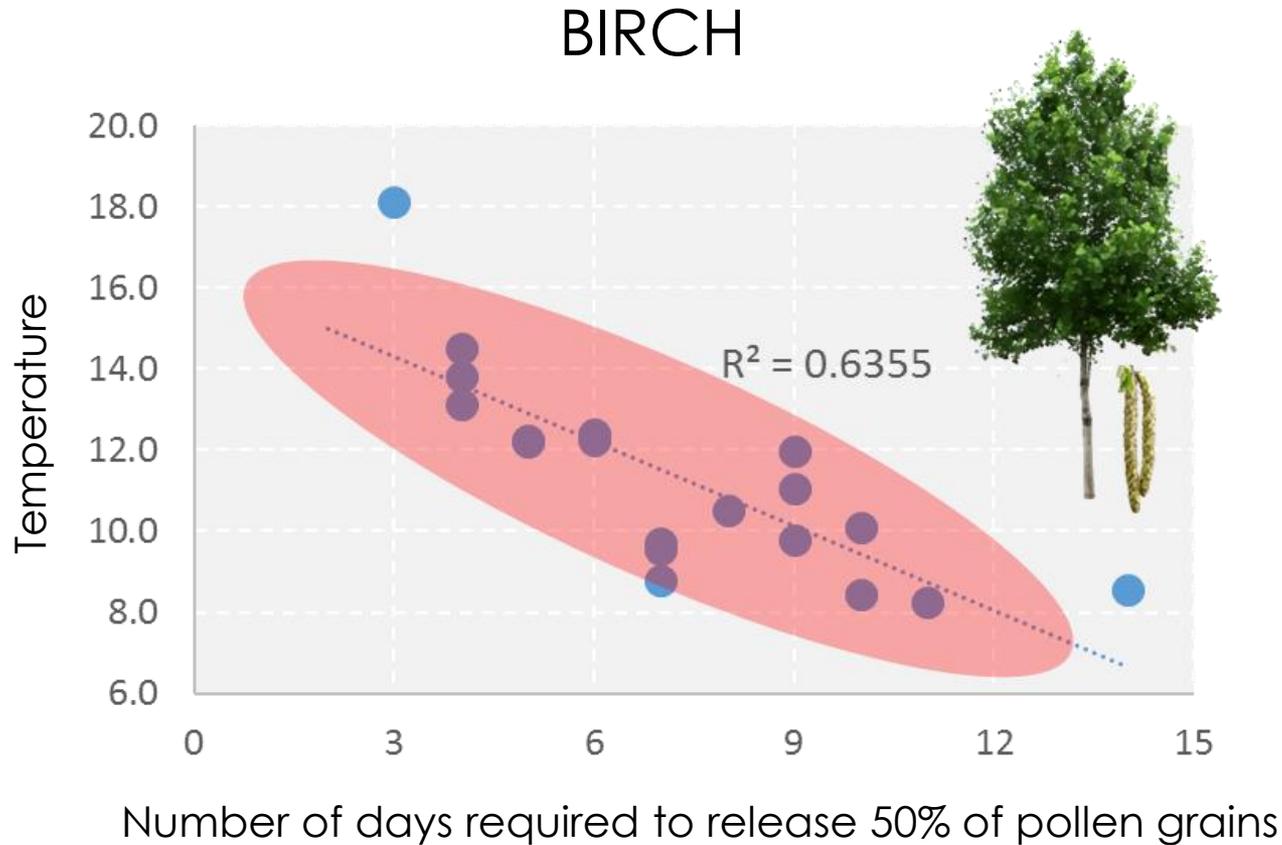
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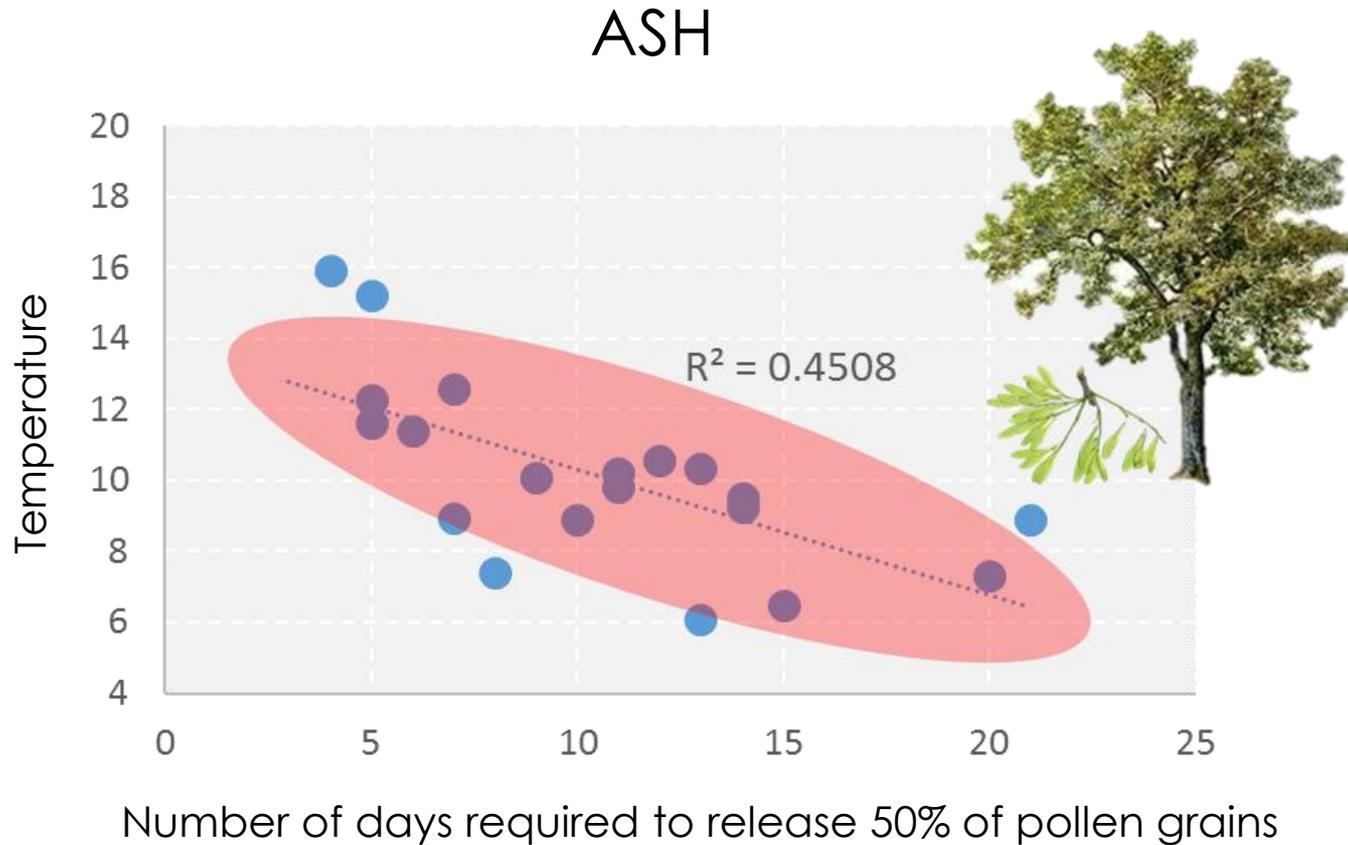
Temperature regulates the pace of pollen release from anthers



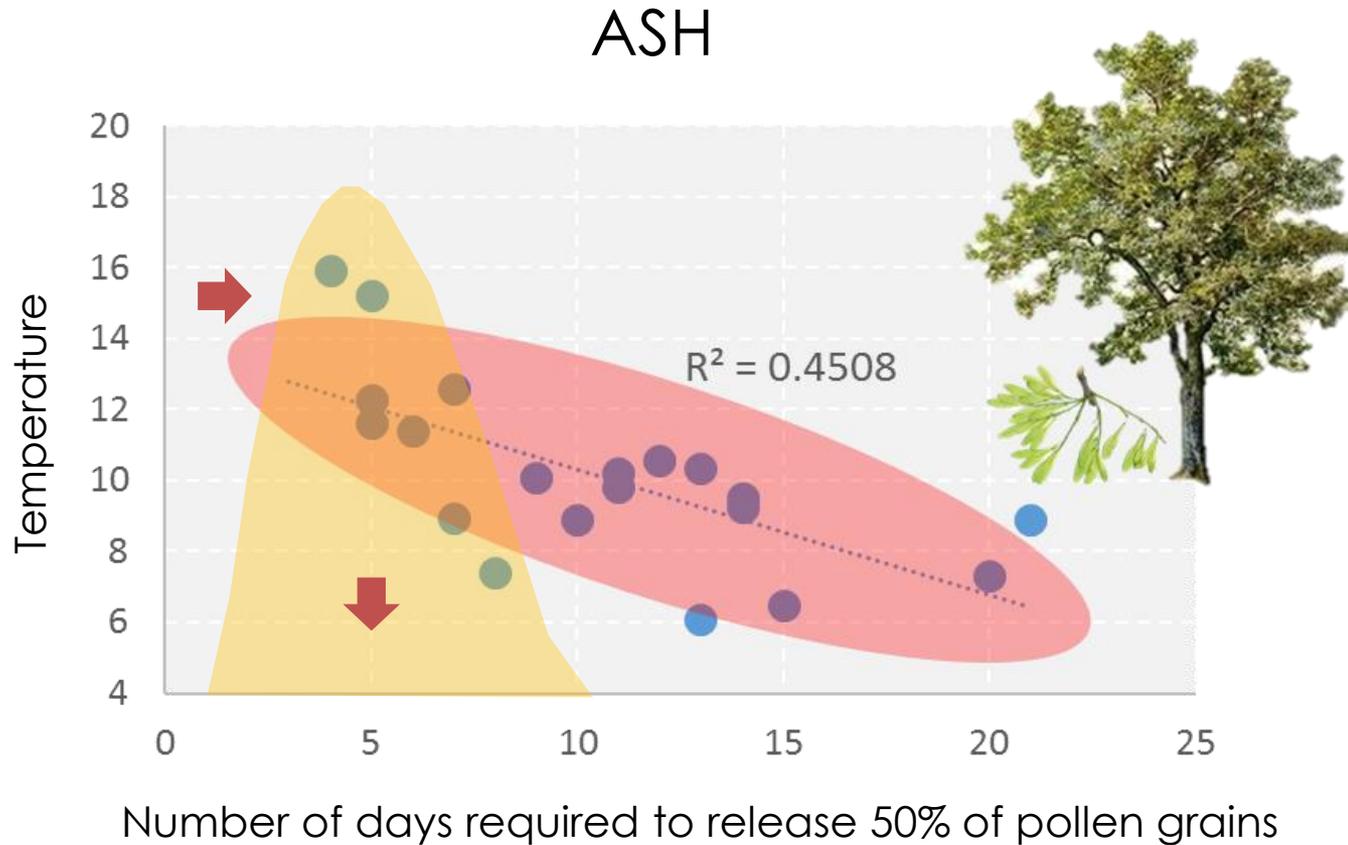
Temperature regulates the pace of pollen release from anthers



Temperature regulates the pace of pollen release from anthers



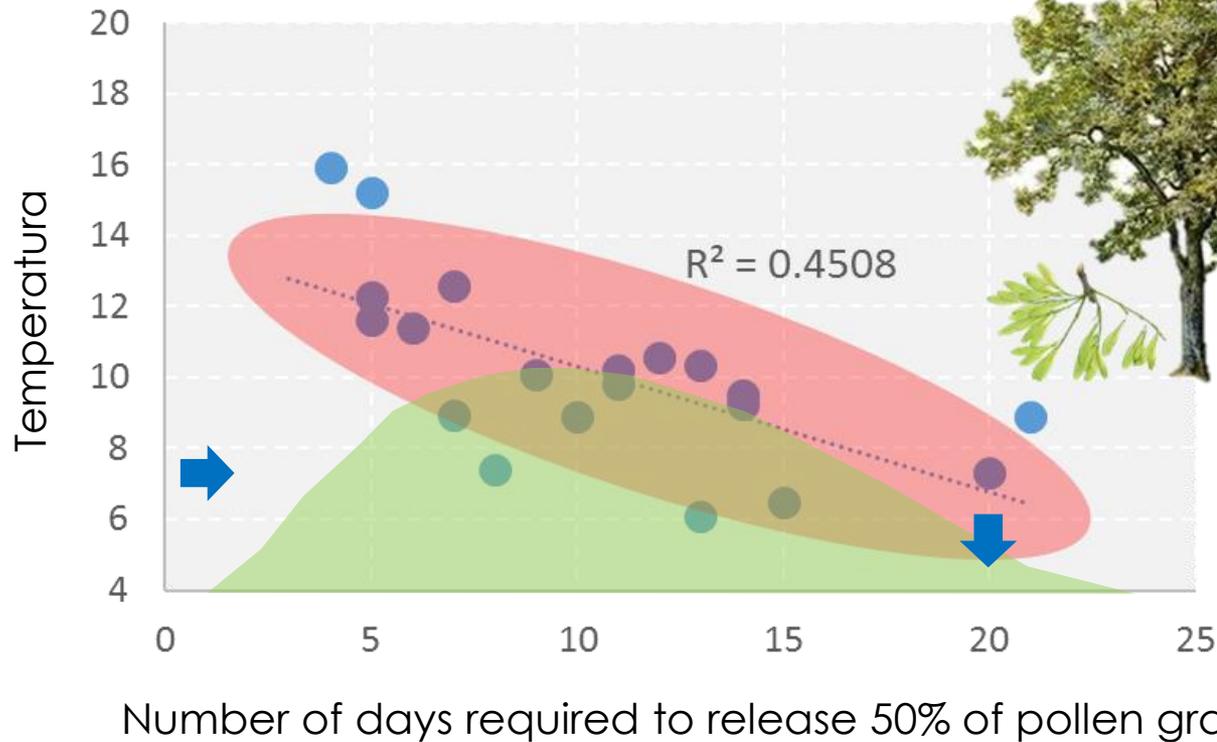
Temperature regulates the pace of pollen release from anthers



Temperature regulates the pace of pollen release from anthers

2x temperature decrease

ASH



Duration of pollen seasons of weeds in Poznań

Table 4 Mann–Kendall trend test (test Z column) and Sen’s slope estimate (Q column) of pollen season parameters of weed taxa

Pollen season parameter	Poaceae		<i>Rumex</i> spp.		Urticaceae		<i>Artemisia</i> spp.	
	Test Z	Q	Test Z	Q	Test Z	Q	Test Z	Q
Start date (DOY)	-2.12*	-1.03	-0.59	-0.31	-1.04	-0.39	-2.86**	-0.75
End date (DOY)	2.7**	1.86	2.66**	2.81	2.60**	1.41	2.26*	1.27
Peak date (DOY)	-0.27	-0.22	1.40	1.56	-1.22	-0.79	0.46	0.10
Duration (days)	3.52**	3.00	2.75**	3.76	2.12*	2.00	2.75**	2.49
Peak value (P/m ³)	-0.81	-6.56	-1.67	-1.50	0.41	7.96	-1.76	-7.32
SPI (pollen)	-0.41	-58.5	-1.22	-11.75	1.49	517.17	-2.12*	-81.33

* $p < 0.05$; ** $p < 0.01$

+2-4 day/year



grasses



sorrel



nettle



mugwort

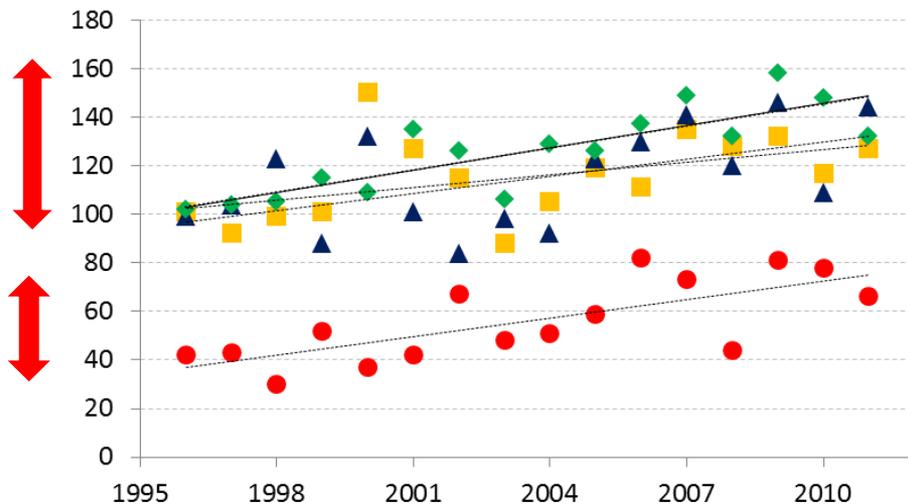
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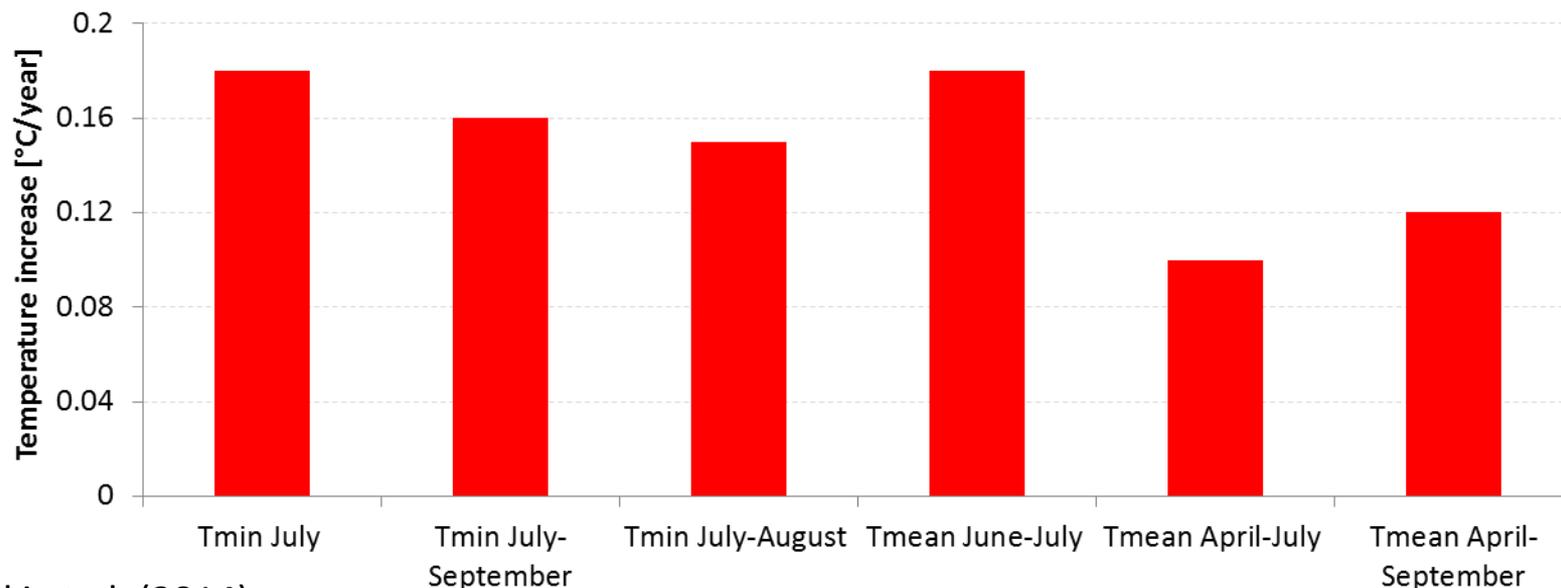


Duration of pollen seasons of weeds in Poznań

Table 4 Mann–Kendall trend test (test Z column) and Sen’s slope estimate (Q column) of pollen season parameters of weed taxa

Pollen season parameter	Poaceae		<i>Rumex</i> spp.		Urticaceae		<i>Artemisia</i> spp.	
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Duration (days)	3.52**	3.00	2.75**	3.76	2.12*	2.00	2.75**	2.49
Peak value (P/m^3)	-0.81	-6.56	-1.67	-1.50	0.41	7.96	-1.76	-7.32
SPI (pollen)	-0.41	-58.5	-1.22	-11.75	1.49	517.17	-2.12*	-81.33

* $p < 0.05$; ** $p < 0.01$



Duration of pollen seasons of weeds in Poznań

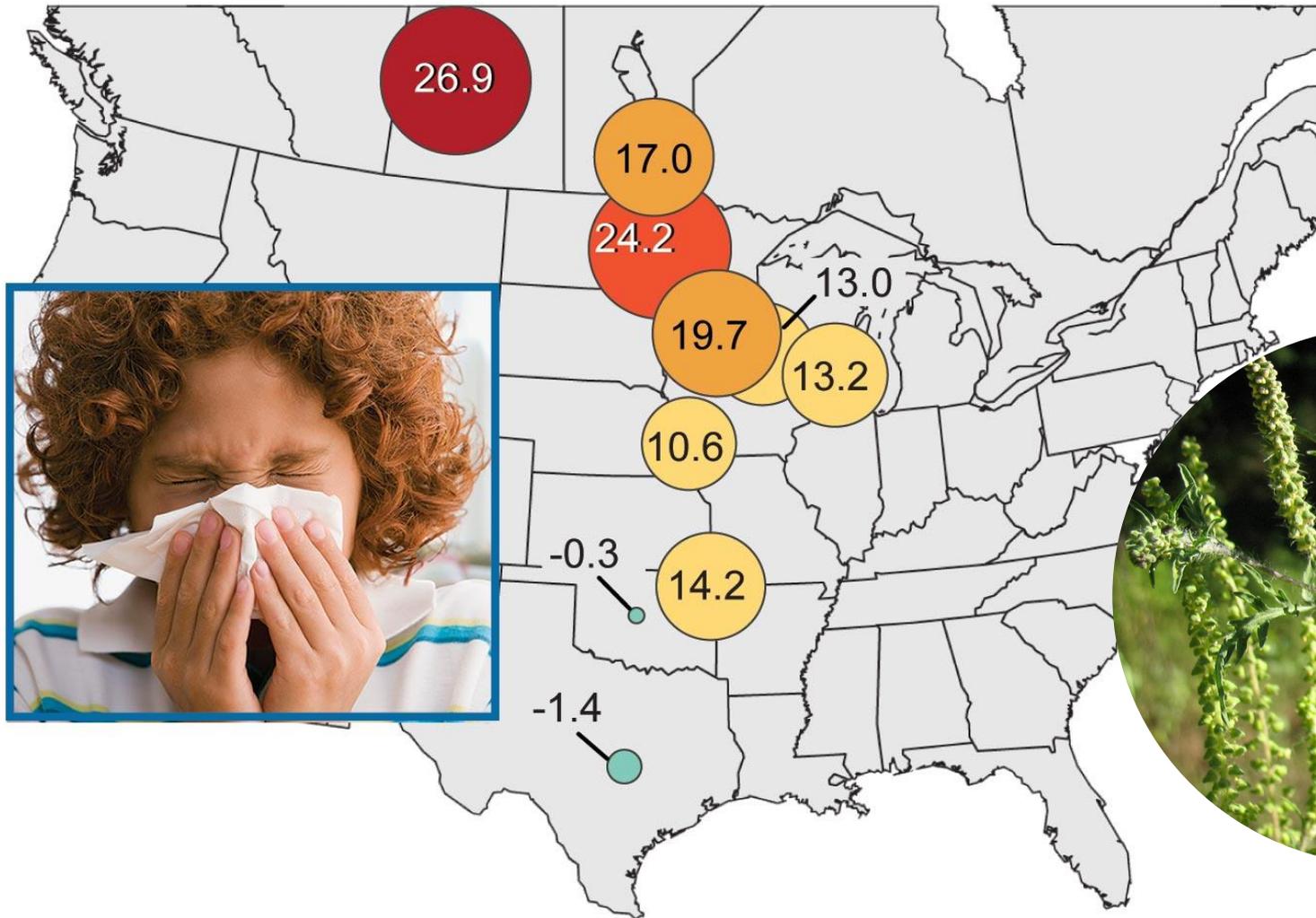
Table 4 Mann–Kendall trend test (test *Z* column) and Sen’s slope estimate (*Q* column) of pollen season parameters of weed taxa

Pollen season parameter	Poaceae		<i>Rumex</i> spp.		Urticaceae		<i>Artemisia</i> spp.	
	Test <i>Z</i>	<i>Q</i>	Test <i>Z</i>	<i>Q</i>	Test <i>Z</i>	<i>Q</i>	Test <i>Z</i>	<i>Q</i>
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* $p < 0.05$; ** $p < 0.01$

Taxon	$T_{\text{mean April-July}}$	$T_{\text{mean April-September}}$	$T_{\text{mean June-July}}$	$T_{\text{min July}}$	$T_{\text{min July-August}}$	$T_{\text{min July-September}}$
Poaceae	ns	ns	0.536*	0.649**	0.780**	0.830**
<i>Rumex</i> sp.	ns	ns	ns	ns	ns	ns
Urticaceae	ns	ns	ns	ns	ns	ns
<i>Artemisia</i> sp.	0.532*	0.691**	0.686**	0.732**	0.670**	0.750**

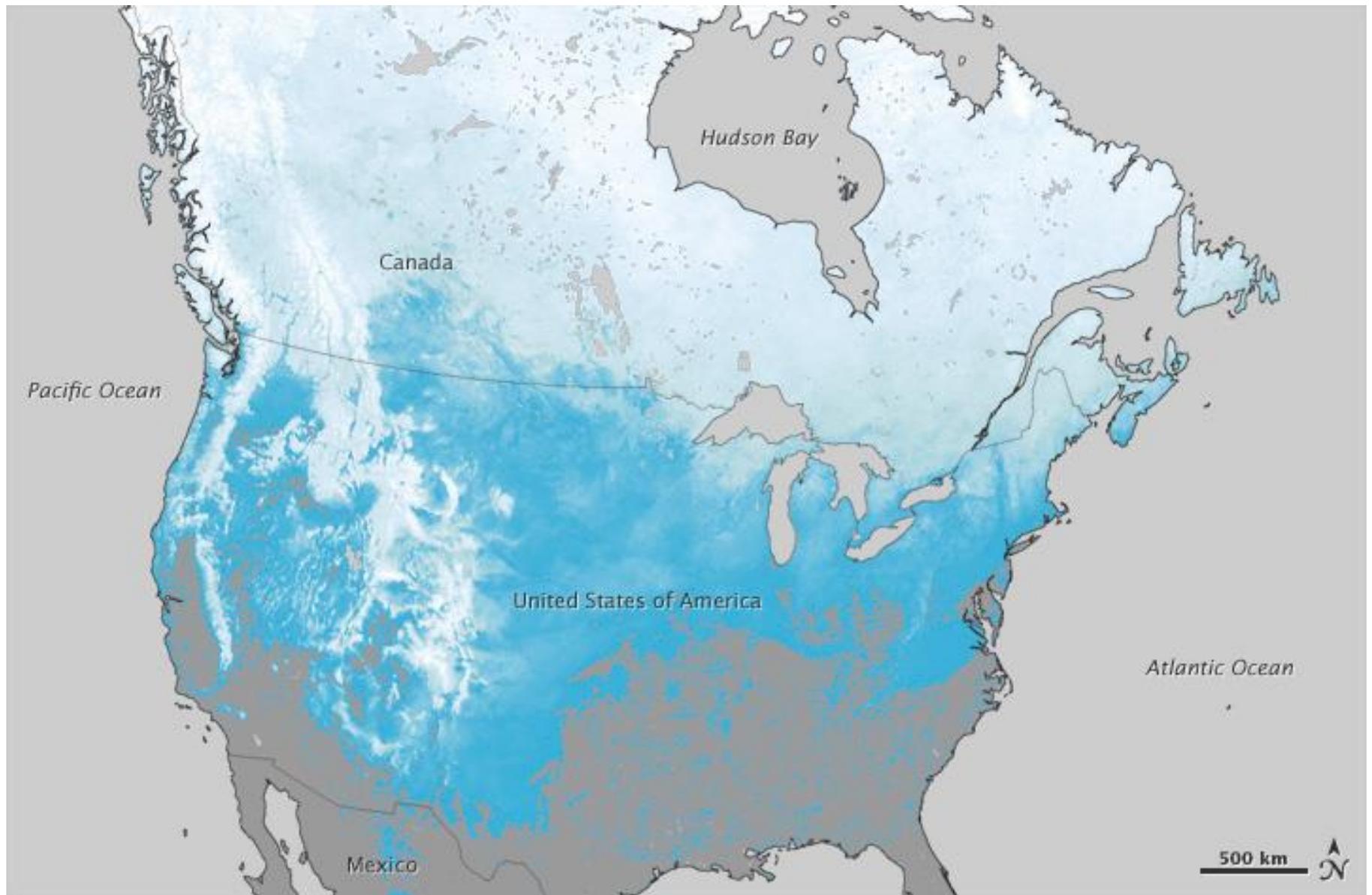
RAGWEED pollen seasons in North America



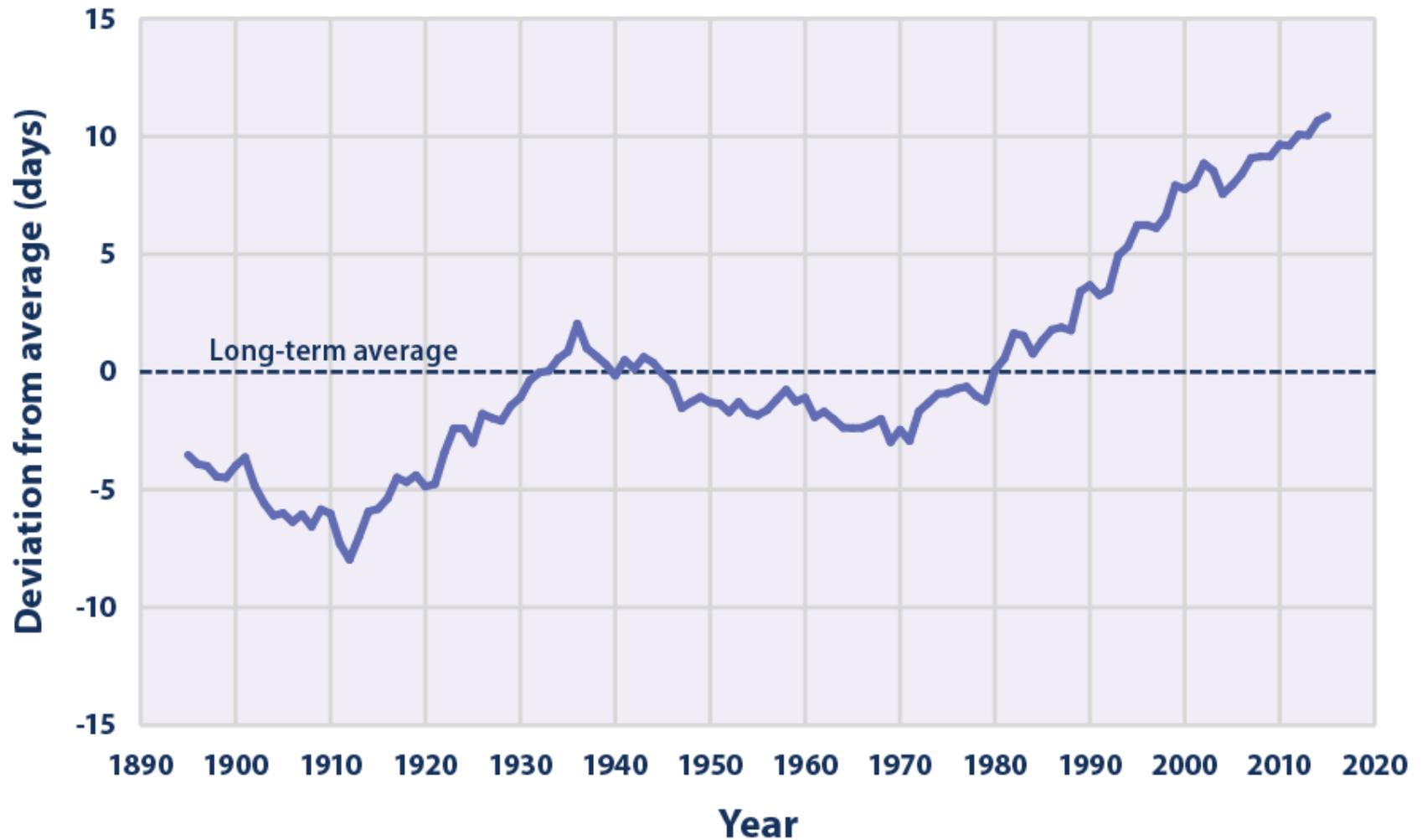
Change in Ragweed Season Length (Days)



Number of days before the first frost

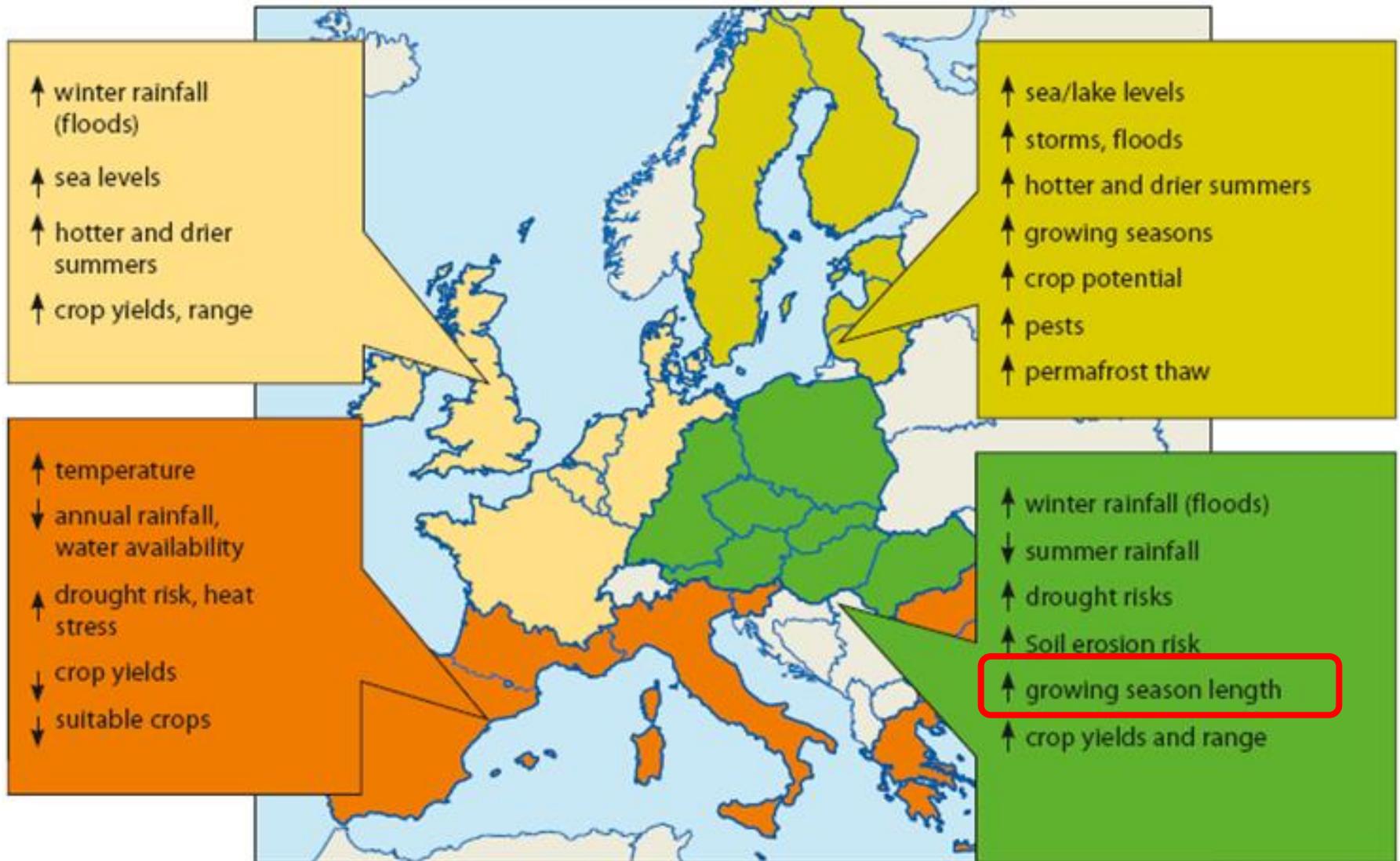


Length of Growing Season in the Contiguous 48 States, 1895–2015

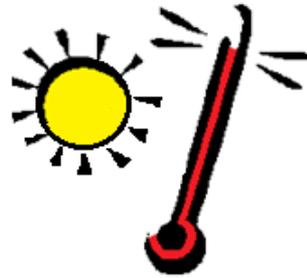


Data source: Kunkel, K.E. 2016 update to data originally published in: Kunkel, K.E., D.R. Easterling, K. Hubbard, and K. Redmond. 2004. Temporal variations in frost-free season in the United States: 1895–2000. *Geophys. Res. Lett.* 31:L03201.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.



The effect of temperature on pollen season duration is not the same and varies depending on plant type, i.e. trees and weeds



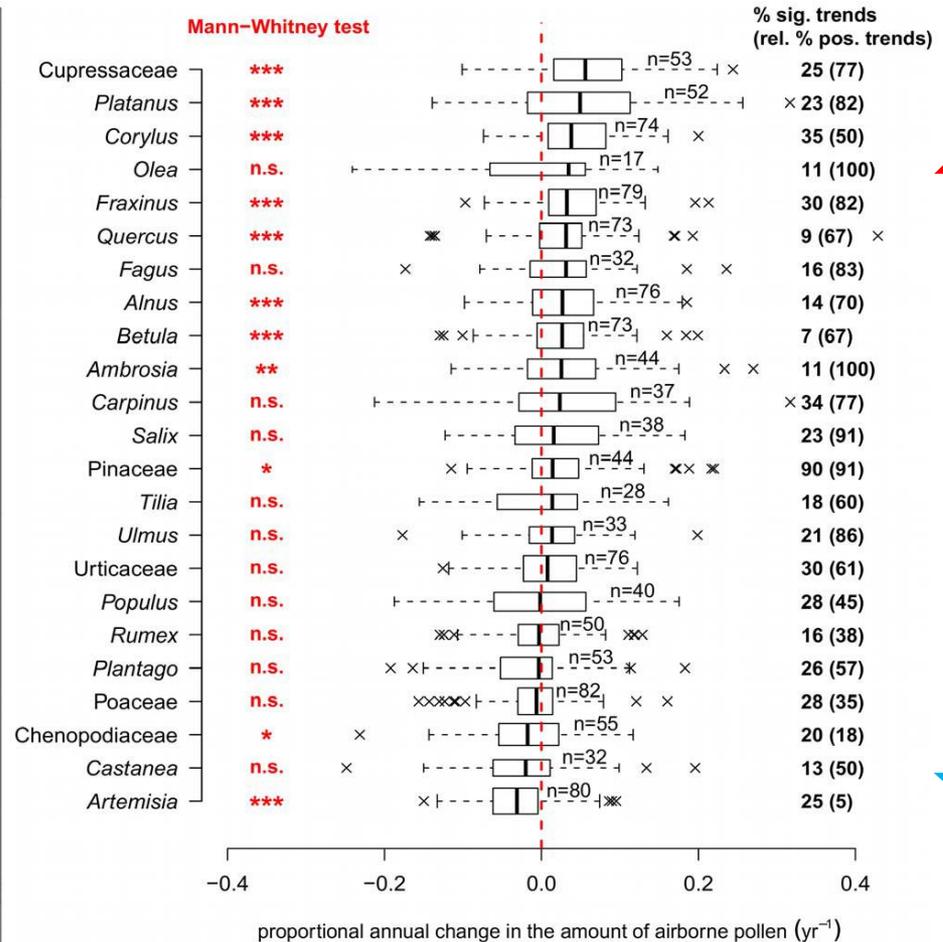
TREES

WEEDS

Shorter seasons

Longer seasons

Intensity of pollen seasons



Intensity of pollen seasons of most of the plants is **increasing**

Development of plants and pollen production depends on weather conditions

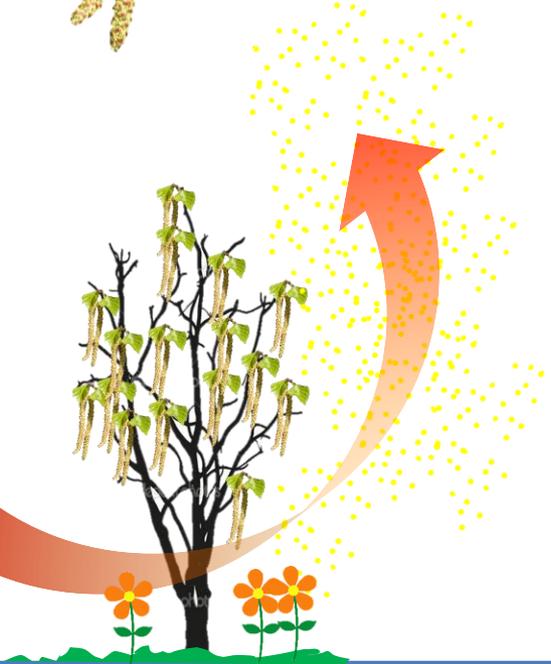
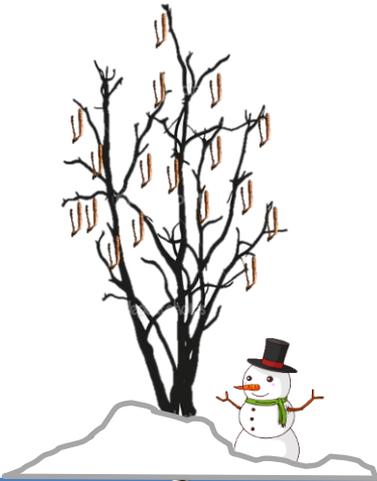
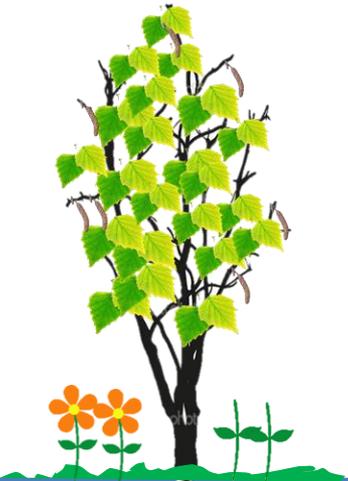
Male catkins of birch

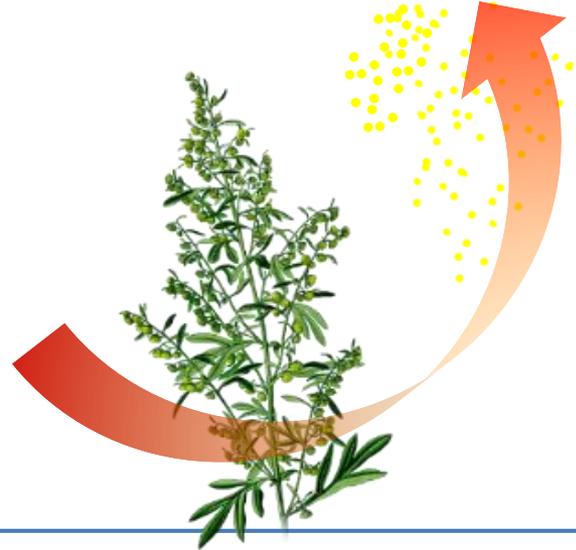
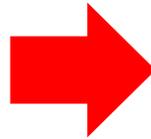
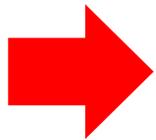
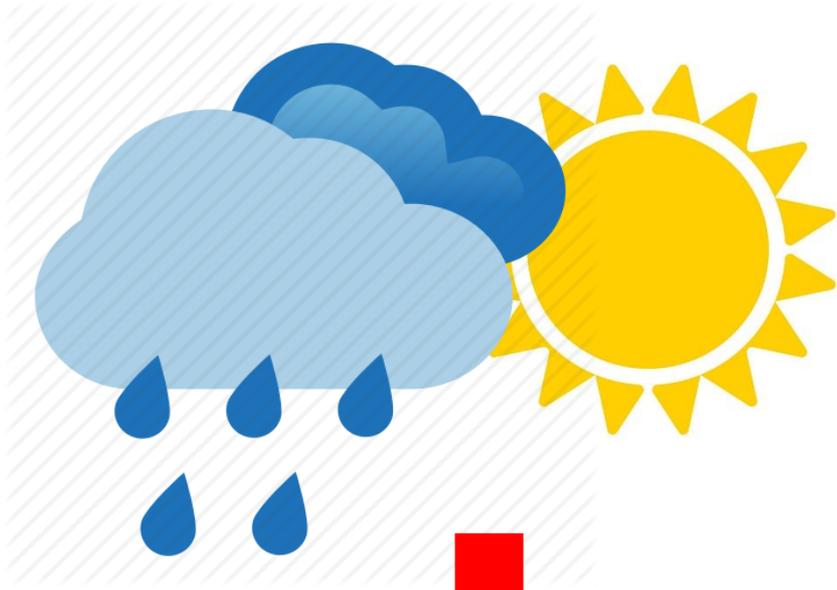


Summer-autumn

Winter

Spring





Spring

Summer

Temperature does not influence markedly on pollen season intensity

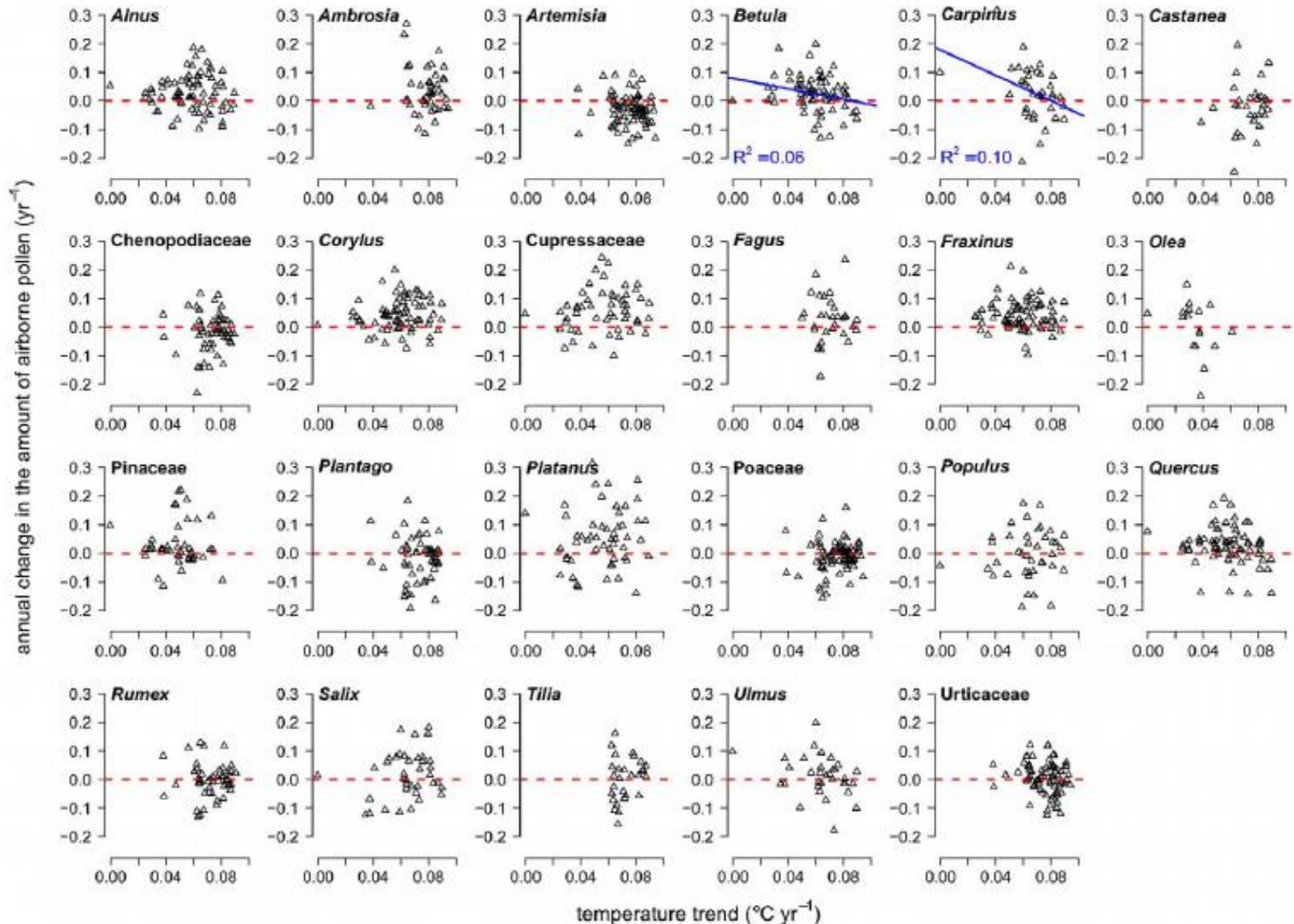


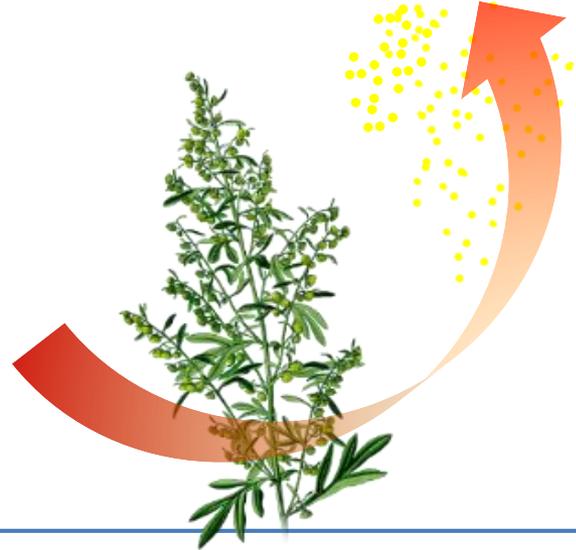
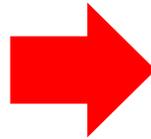
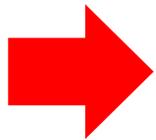
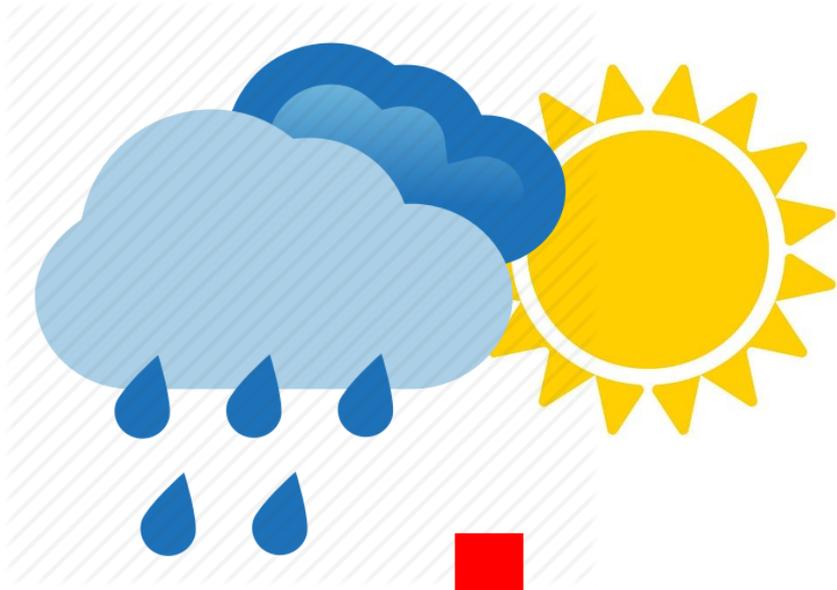
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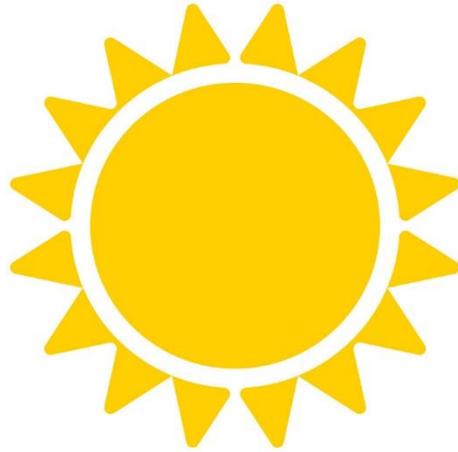
	T_{mean} June–July	T_{min} July	T_{min} July–August	T_{min} July–September
ns	ns	–	–	–
ns	0.515*	0.627*	0.670**	–
0.536*	0.649**	0.780**	0.830**	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
–	–	–	–	–
ns	ns	–	–	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
–	–	–	–	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
-0.728**	-0.805**	–	–	–
ns	ns	ns	ns	–
ns	ns	ns	ns	–
0.686**	0.732**	0.670**	0.750**	–
-0.629*	-0.547*	ns	-0.635**	–
-0.571*	-0.521*	-0.615*	-0.644**	–



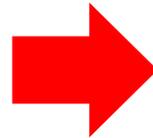
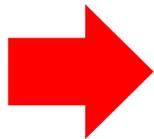
Spring

Summer

drought



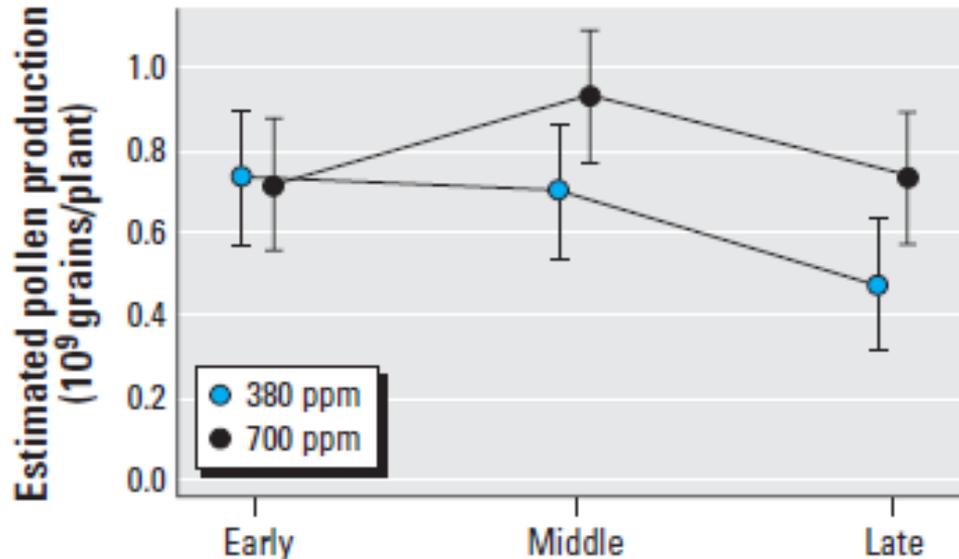
Low pollen level



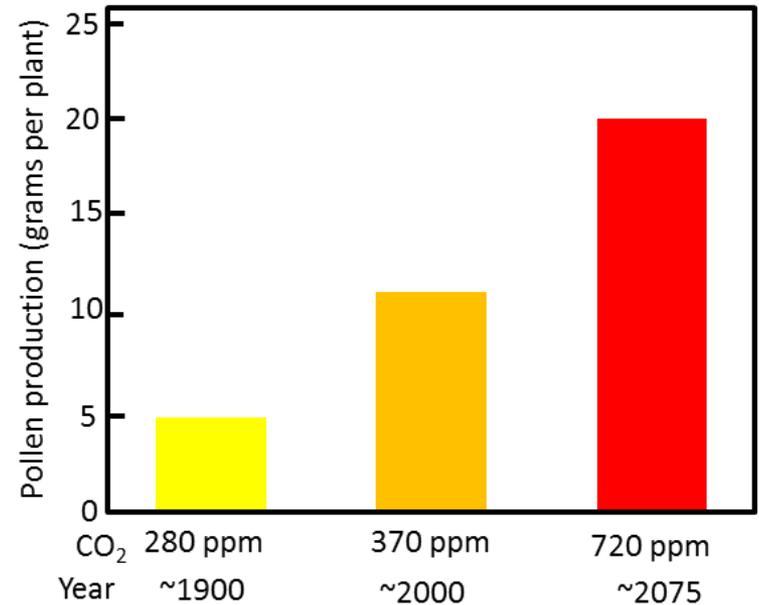
Spring

Summer

CO₂ and the production of pollen grains



„At **high CO₂ levels**, plants showed greater biomass and reproductive effort compared with those in ambient CO₂. Overall, ragweed **pollen production can be expected to increase significantly** under predicted future climate conditions” (Rogers et al. 2006).



„Under future predicted greenhouse gas emissions and associated climate conditions (...), there will be an overall **increase in ragweed pollen production.**” (Ziska and Caulfield, 2000)

MORE CO₂ = MORE POLLEN

25

Pollen Production

20

15

10

5

0

1900 / **280**
ppm

2000 / **370**
ppm

2060 / **600**
ppm

Pollen Production: Grams Per Ragweed Plant

Source: Ziska et al. 2000

CLIMATE  CENTRAL

In summary...



**Pollen seasons start earlier
Pollen seasons are shorter
Pollen seasons more intense?**



**Pollen seasons start earlier
Pollen seasons are longer
Pollen seasons more intense**