

Decrease or increase? Temporal changes in pollen concentrations assessed by Bayesian statistics

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Abstract Aerobiological studies mostly apply linear models when analysing long-term changes in pollen concentrations. There is some evidence that linear models are not fully suitable for describing these changes in recent decades since pollen concentrations of some species have increased until 1990 and decreased subsequently. In order to describe the behaviour of annual pollen concentrations (a factor contributing to the incidence of allergies) in a more flexible way, we made use of Bayesian statistics that describe discontinuities (i.e. change points) and quantify the direction and speed of changes. We examined long-term aerobiological pollen data of

Betula spp. (birch), *Corylus* spp. (hazel) and Poaceae (grasses) from six stations in Switzerland (Basel, Buchs, Davos, Münsterlingen, Neuchâtel and Zurich) for the period 1985–2014. For most of the analysed stations and species, the one change point model was considered as the best model. The only exceptions were *Corylus* pollen time series recorded at Neuchâtel and Zurich that could be better described with the linear model. The results indicated that all pollen records of *Corylus* were characterized by increased pollen concentrations in recent years. For *Betula* pollen concentrations, four sites were associated with recent decreases; increases were only found for Buchs and Münsterlingen. Regarding Poaceae pollen, half of the stations ($N = 3$) were linked to decreases. Trends of linear regressions differed considerably in magnitude or even differed in sign compared to the Bayesian results. Our results indicate that the choice of the statistical method is of major importance when interpreting aerobiological data. Further studies should focus on the reasons (climate, land use changes, etc.) responsible for changes in atmospheric pollen loads in detail.

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1 Introduction

Allergies pose a major risk to human health. The World Health Organization (WHO) reported that 30–40% of the global population shows allergic sensitisation (Pawankar et al. 2011). In many countries, the most common form of allergy is hay fever (Langen et al. 2013) mediated by allergenic species such as birch or grass (D'Amato et al. 1991). Epidemiological studies in Switzerland for example revealed an increase in pollen allergies from 0.82% in 1926 (Rehsteiner 1926) to more than 11% in 1993 (Wüthrich et al. 1995). Recently, some epidemiological studies also reported a flattening of the rate of new sensitisations in the 1990s (Braun-Fahrlander et al. 2004; Grize et al. 2006) opening a renewed discussion on the influence of pollen concentration on the prevalence of hay fever (Frei and Gassner 2008b).

In general, many factors have been discussed that may contribute not only to more frequent and severe occurrence of respiratory symptoms but also to new allergen sensitisation and increases in the development of allergic diseases (Beggs 2004). Besides air pollution (D'Amato et al. 1991) and a westernized lifestyle (Nowak et al. 1998; Matricardi 2001; Ring et al. 2001), the impact of airborne quantities of allergenic pollen is among the most important factors discussed (de Weger et al. 2013; Smith et al. 2014). Wüthrich et al. (1995) observed that hay fever prevalence is less frequent among people living at higher elevations where pollen abundance is generally lower (Frei 1997; Gehrig and Peeters 2000; Jochner et al. 2012, 2015). Thus, pollen abundance might influence the severity of allergic diseases and sensitisations.

Although it was proposed that the increase in the observed pollen concentration goes hand in hand with the observed increase in pollen allergies (Frei 1998), there are suggestions that the increasing prevalence of pollinosis in the second part of the twentieth century (Wüthrich 1989) is not related to pollen abundance since pollen concentration has not provided convincing explanations for the steep rise in allergies in former decades (Clot 2003). In addition, the effects of pollen exposure on the prevalence of sensitisations are still not satisfactorily understood (de Weger et al. 2013) and it was reported that there is no relationship between annually averaged pollen concentrations and sensitisation rates in Europe (Burr et al. 2003). Poly-

sensitization and cross-reactivity (Frenguelli et al. 2010) may further complicate a simple cause–effect relationship. Thus, a variety of determinants governs the development of allergies which makes it difficult to attribute the effects of changing pollen concentrations on the development of allergic diseases.

Some studies indeed detected a lower pollen concentration for a variety of species in the last two decades (e.g. Clot 2003; Ugolotti et al. 2015). Grass pollen in particular was often associated with non-significant changes or even decreases (Leuschner et al. 2000; Voltolini et al. 2000; Ziello et al. 2012), a fact that might also be attributed to changes in land management (Emberlin et al. 1999; Ghitarrini et al. 2016). On the other hand, an increase in pollen concentration was also documented for a number of species at several locations, especially for tree and *Ambrosia* pollen (e.g. Simoleit et al. 2016; Fuhrmann et al. 2016; Ziello et al. 2012). A European study covering the full range of *Ambrosia artemisiifolia* distribution suggested that the direction of pollen trends varied locally and clearly reflected changes in plant distribution (Sikoparija et al. 2017). Biotic influences such as the accidental introduction of the leaf beetle *Ophraella communa*, e.g. in Northern Italy, are linked to lower atmospheric *Ambrosia* pollen concentrations (Bonini et al. 2016).

In general, aerobiological studies mostly apply linear models when analysing changes in pollen concentrations over time (e.g. Clot 2003; Ziello et al. 2012; Smith et al. 2014). However, there is some evidence that linear models are not fully suitable for describing changes in recent decades, especially when increases in pollen concentrations are followed by decreases (and vice versa) and the possibility of reaching a plateau in pollen concentrations is discussed (Clot 2003).

Frei and Gassner (2008b) showed that the concentration of birch and grass pollen in Basel was associated with an increase until 1990 followed by a decrease in the subsequent period. With linear models calculated for two arbitrary sub-periods, they confirmed their assumption. In another study (Frei and Gassner 2008a), they used the sequential Mann–Kendall test for time series and found potential turning points in 1982 and 1991.

To unveil recent trends in pollen concentrations, there is a need for further analyses of aerobiological time series and additionally for applying more

sophisticated methods. To describe aerobiological changes mathematically, the use of Bayesian statistics seems appropriate. The Bayesian methodology helps us to describe important discontinuities and to quantify the direction and speed of changes and allows a rigorous treatment of uncertainties when determining model and change point probabilities, mean functional behaviours and rates of change (Dose and Menzel 2004; Henneken et al. 2013; Pope et al. 2013; Jochner et al. 2015).

For the first time, we apply Bayesian change point analysis to aerobiological data and test whether these techniques are appropriate for a better understanding of changes in airborne pollen concentrations. We focus on examining whether there is a considerable change in pollen concentrations determined by the change point method. In order to compare our results with traditional methods, the data are also analysed using linear models. These evaluations will further help to assess the risk of pollen allergy in more detail.

2 Materials and methods

2.1 Pollen monitoring sites

We examined long-term aerobiological pollen data of species associated with a high allergenic impact (D'Amato et al. 1991): *Betula* spp. (birch), *Corylus* spp. (hazel) and Poaceae (grasses). These data derive from the national pollen monitoring network operated by the Federal Office of Meteorology and Climatology MeteoSwiss in Switzerland and covers the 30-year period 1985–2014. The metric used was the annual pollen integral (API_n), the sum of average daily concentrations during the whole season, expressed as pollen * day m⁻³ (Galán et al. 2017). The criteria for selection of the data series were a maximum of two missing values in the beginning of the time series (1985 and 1986) and a maximum of three missing values in total. Thus, six stations were selected for pollen concentrations of *Betula* and Poaceae (Basel, Buchs, Davos, Münsterlingen, Neuchâtel and Zurich, see Fig. 1 and Table 1) and four stations for *Corylus* (Basel, Buchs, Neuchâtel and Zurich, see Fig. 1 and Table 1). Although longer time series were available for some stations, we only analysed the data from 1985 onwards for comparability.

Pollen monitoring was based on the standard equipment and methods proposed by the European Aerobiology Society (EAS; Galán et al. 2014): Sampling was achieved with a volumetric pollen trap (Hirst type, Burkard Manufacturing Co. Ltd., UK) containing a pump aspirating 10 litres of air per minute through a 14 × 2 mm orifice. Pollen was impacted on a silicon-coated plastic strip adhered to a rotating drum that is changed once a week and sent to the analysis centre where daily pollen samples are prepared. Using light microscopy, pollen was counted along two longitudinal transects, representing ~ 5% of the slides.

2.2 Statistical analyses

In order to flexibly describe the time series of pollen concentrations, we made use of Bayesian statistics that characterise discontinuities (i.e. change points) and quantify the direction and speed of changes.

Three different model types, a constant, a linear and a one change point model, were tested to describe the observational time series of API_n. Initially, we also analysed our observational time series in terms of a multiple change point model (Henneken et al. 2013), but since the data did not fit best with a higher number of change points, the analyses were restricted to the one change point model following the approach by Dose and Menzel (2004). The constant model assumes a constant API_n over the years, the linear model a linear change of API_n numbers with year; whereas the one change point model assumes for a time series of 27–30 years two linear segments with a matching change point (cpt) resembling a polygon. In the latter case, for a time series of N years $N-2$ possible polygon functions have to be assessed in the Bayesian nonparametric function estimation. Based on all possibilities, the one change point model is then a superposition of the polygons for all $N-2$ configurations weighted with their respective probabilities. The resulting function is no longer a polygon and may show a considerable flexibility, depending on the probabilities of change points in certain years (see Fig. 2c).

To identify the best model option (constant, linear or one change point), the residual sums of squares are not an adequate indicator since the goodness of fit increases with model complexity. The built-in Ockham factor of Bayesian probability theory (Garrett

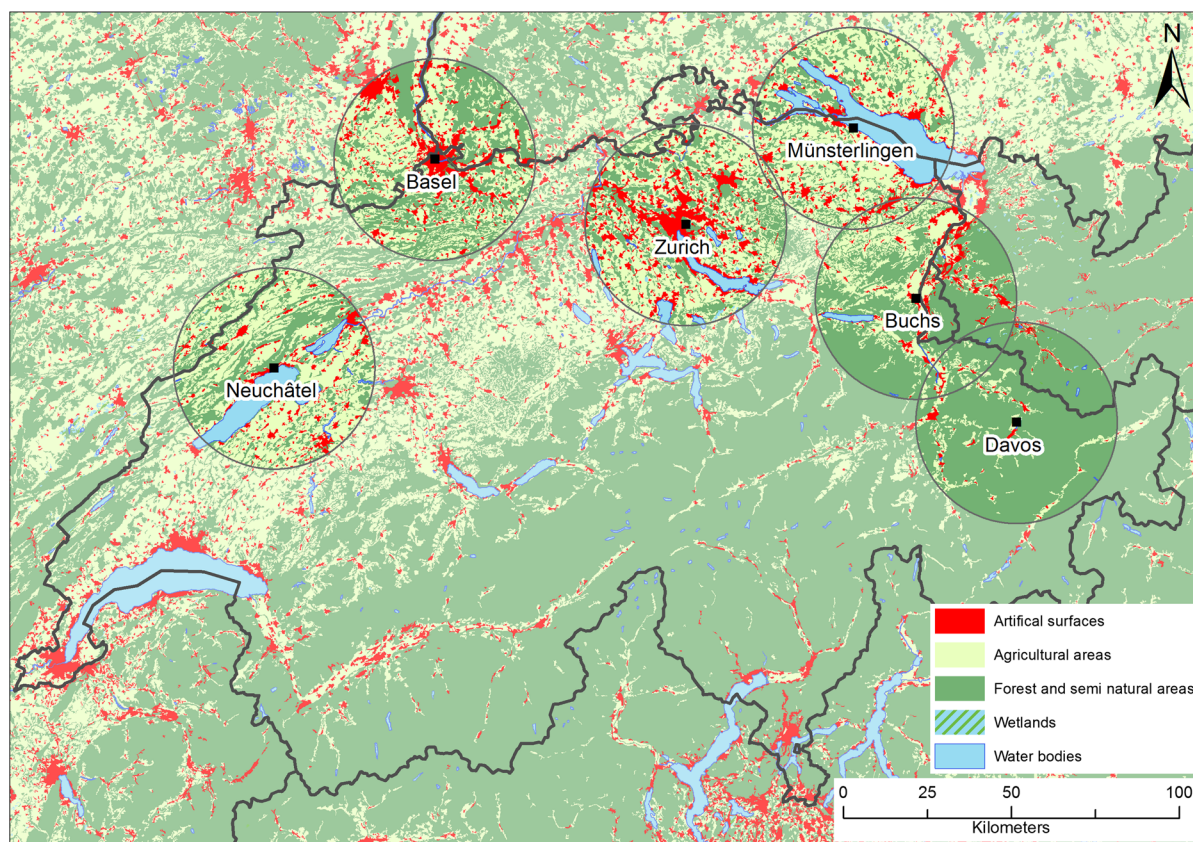


Fig. 1 Location of the six selected pollen monitoring stations of the MeteoSwiss network in Switzerland; buffer size: 30 km. Background: level 1 categories of CORINE land cover (CLC) data 2012 (The European Environment Agency 2016b)

Table 1 General information on the selected pollen monitoring stations of the MeteoSwiss network in Switzerland

	Latitude (°N)	Longitude (°E)	Elevation (m)	Artificial surfaces in a 2 km radius (2012) (%)	Change in agricultural area (1990–2012) (%)	<i>Corylus</i> <i>N</i>	<i>Betula</i> <i>N</i>	<i>Poaceae</i> <i>N</i>
Basel	47.56	7.58	273	93.70	− 0.4	30	30	30
Buchs SG	47.17	9.47	445	40.30	NA	27	30	28
Davos	46.83	9.85	1600	0.04	0.5	–	28	30
Münsterlingen	47.63	9.24	410	12.00	3.3	–	28	27
Neuchâtel	47.00	6.95	490	27.00	− 2.2	28	30	30
Zurich	47.38	8.57	556	40.96	4.6	27	29	30

N number of years. The percentage of artificial surfaces is based on CORINE land cover (CLC) 2012 (The European Environment Agency 2016b). The change in agricultural area within the period 1990–2012 was obtained from CORINE land cover data (1990, 2012); (The European Environment Agency 2016a, b; Swiss Federal Statistical Office (SFSO) & Federal Office for the Environment (FOEN) 1998) and given in % for a radius of 30 km. Data for Buchs could not be assessed since the 30-km radius comprises parts of the country Lichtenstein where no land cover data were available

1991) counter balances this effect and the comparison of the three model types is based on the respective Bayesian model probabilities (see Table 2).

For the selected model type, we calculated the estimates of the fit function and their associated uncertainties (confidence intervals). The derivatives of

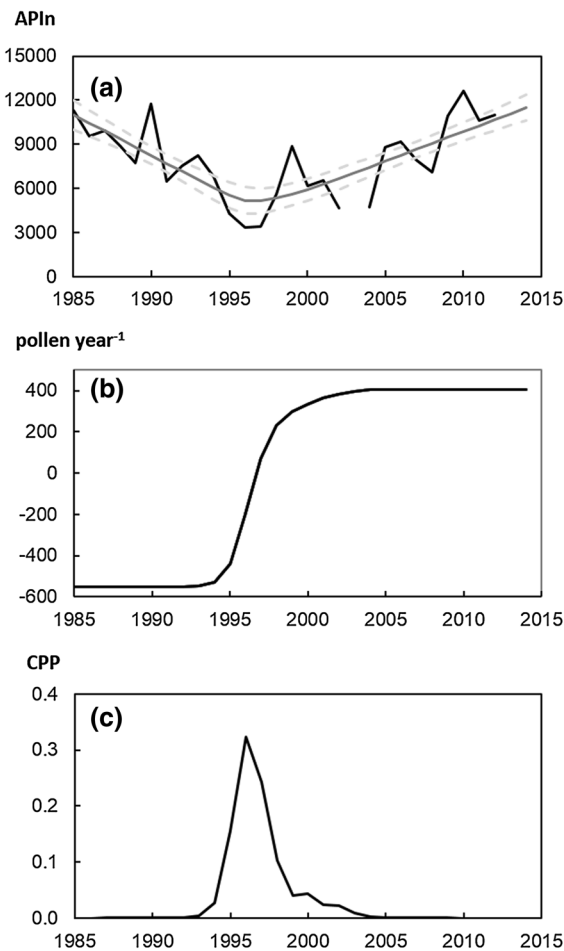


Fig. 2 **a** Black curve: observed APIn of Poaceae in Buchs, grey solid line: estimates of the fit function, grey dashed line: confidence intervals ($\pm$ standard error) around the expectation value. **b** Corresponding rates of changes (pollen year⁻¹) indicating decreases (negative values) or increases (positive values). **c** Normalised change point probability (CPP) distribution

the fit function (trends) correspond to the rate of change in pollen year⁻¹ for pollen data (positive values: increase, negative: decrease). An example for estimates of the fit function, the corresponding rates of changes and the normalised change point probability (CPP) distribution can be seen in Fig. 2. The year of the maximum of the CPP distribution is referred to as change point year. Thus, the trend changes with time and has therefore to be specified as trend (pollen year⁻¹) for a specific year. Here, the trend of the pollen numbers is given for the last year of our analysed record, for 2014. Further details on the

methodology of change point analyses can be found in Dose and Menzel (2004, 2006).

Linear models based on the least square fitting technique were used to additionally provide linear trends and their associated significance values for temporal changes in pollen concentrations using IBM SPSS Statistics 22.0.

3 Results

For all analysed stations and species (except for *Corylus* at Neuchâtel and Zurich), the one change point model was considered as the best model (see Table 2). Model probabilities for the one change point model were 0.508 and 0.539 for *Corylus* and varied between 0.355 and 0.817 for *Betula* and between 0.451 and 1.000 for Poaceae.

The location of the change point was found in 1999 and 2000 for *Corylus*, between 1995 and 2004 for *Betula* and between 1994 and 2002 for Poaceae (see Table 2 and Figs. 2, 3, 4).

The trend in *Corylus* pollen concentrations calculated within the Bayesian approach (T 2014) was positive for all analysed stations and was 75.3 (Buchs) and 77.8 (Basel) pollen year⁻¹ in 2014. For comparison, we also present the trend of a linear regression model (T linear). Trends for the Bayesian approach are always given for the year 2014, while the linear trend is valid for the whole data series. The linear trend is less pronounced for both cases (50.7 and 42.4 pollen year⁻¹, see Table 2). In Neuchâtel and Zurich, where the linear model (model probability: 0.517 and 0.508) was found to be superior to the change point model (model probability: 0.475 and 0.492), the trends were also positive, indicating an increase in pollen concentrations over time (30.9 and 108.5 pollen year⁻¹).

At four stations (Basel, Davos, Neuchâtel and Zurich), *Betula* pollen data analysed with the Bayesian method were associated with decreases ranging between -20.3 and -525.1 pollen year⁻¹. Increases were recorded at Buchs (633.7 pollen year⁻¹) and Münsterlingen (59.9 pollen year⁻¹). The linear trend was less pronounced for Basel and Buchs and even differed in sign for Davos, Neuchâtel and Zurich. Note that statistically significant linear trends ($p \leq 0.05$) were only found for Buchs, Davos and Zurich (Fig. 5).

Table 2 Model probabilities for *Corylus*, *Betula* and Poaceae pollen APIn time series (1985–2014) at four to six stations in Switzerland with respect to a constant, linear and one change point (CP) model and the associated year with maximum change point probability

	Model probabilities			Bayesian results		Linear model	
	Constant	Linear	CP	CP Year	T 2014	T Linear	<i>p</i>
<i>Corylus</i>							
Basel	0.024	0.468	0.508	1998.7	77.8	42.4	0.012
Buchs	0.006	0.454	0.539	2000.2	75.3	50.7	0.003
Neuchâtel	0.007	0.517	0.475	NA	NA	30.9	0.003
Zurich	0.000	0.508	0.492	NA	NA	108.5	0.000
<i>Betula</i>							
Basel	0.019	0.215	0.675	1994.9	− 105.1	− 73.4	0.184
Buchs	0.059	0.339	0.602	2000.1	633.7	171.7	0.049
Davos	0.000	0.490	0.509	2000.8	− 20.3	20	0.000
Münsterlingen	0.216	0.353	0.431	2000.3	59.9	91.1	0.249
Neuchâtel	0.330	0.315	0.355	1999.0	− 52.1	16.6	0.558
Zurich	0.004	0.179	0.817	2003.9	− 525.1	209	0.005
<i>Poaceae</i>							
Basel	0.011	0.436	0.553	1996.8	− 130.1	− 155.4	0.005
Buchs	0.000	0.000	1.000	1996.8	405.3	41	0.483
Davos	0.299	0.249	0.451	1998.6	56.9	− 3.5	0.777
Münsterlingen	0.014	0.255	0.731	1997.8	− 68.6	95.5	0.014
Neuchâtel	0.141	0.145	0.715	2002.4	− 177.1	21.8	0.482
Zurich	0.027	0.058	0.915	1993.8	75.5	24.3	0.164

Bold values indicate the respective highest model probability. Trends (T) were calculated with the Bayesian approach and are given for the year 2014 (T 2014) as well as by the conventional linear regression model (T linear); *p* values < 0.05 indicate significance

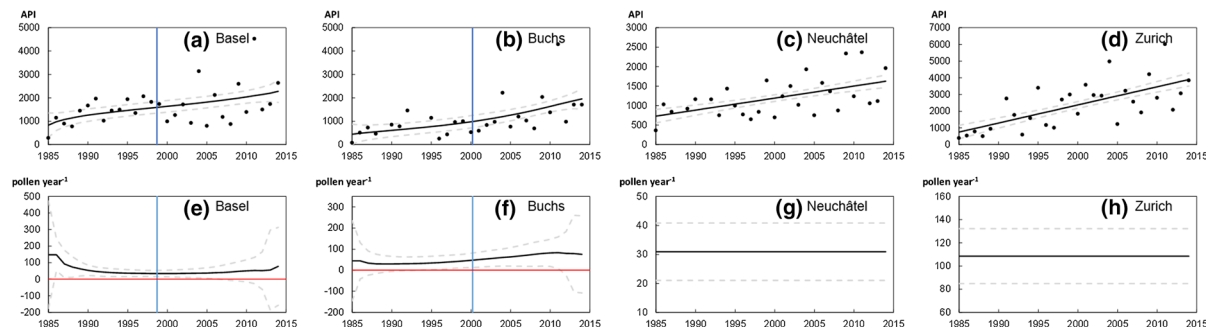


Fig. 3 Model functions for *Corylus* pollen data in **a** Basel, **b** Buchs, **c** Neuchâtel, and **d** Zurich. Black dots: observed APIn, black solid line: estimates of the fit function, grey dashed line: confidence intervals ($\pm$ standard error) around the expectation

According to the Bayesian results, three Poaceae monitoring stations were linked to decreases (Basel, Münsterlingen, Neuchâtel) and three to increases (Buchs, Davos, Zurich). The most pronounced decrease and increase were calculated for Neuchâtel (-177.1 pollen year $^{-1}$) and Buchs (405.3 pollen year $^{-1}$), respectively. Here, these trends also differ considerably in magnitude compared to the linear trends for the whole period and three cases

value, blue vertical line: location of the change point year. **e–h** Black solid lines show the respective derivative (rates of changes) (pollen year $^{-1}$) indicating increases (positive values) or decreases (negative values), red line: zero line

(Davos, Münsterlingen, Neuchâtel) with even different signs of trends were observed. However, linear trends were only significant for Basel and Münsterlingen.

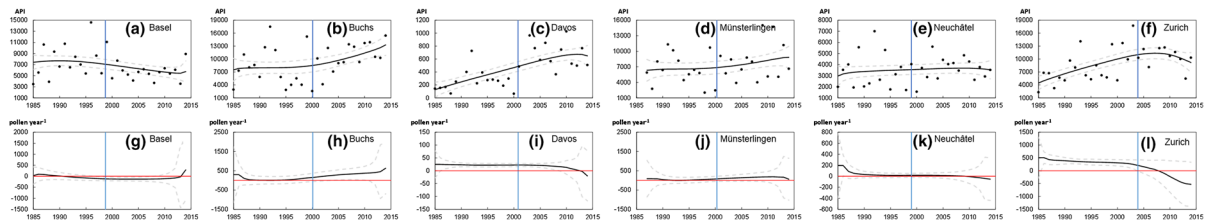


Fig. 4 Model functions for *Betula* pollen data in **a** Basel, **b** Buchs, **c** Davos, **d** Münsterlingen, **e** Neuchâtel and **f** Zurich. Black dots: observed API_n, black solid line: estimates of the fit function, grey dashed line: confidence intervals ($\pm$ standard error) around the expectation value, blue vertical line: location

of the change point year. **g–l** Black solid lines show the respective derivative (rates of changes) (pollen year⁻¹) indicating increases (positive values) or decreases (negative values), red line: zero line

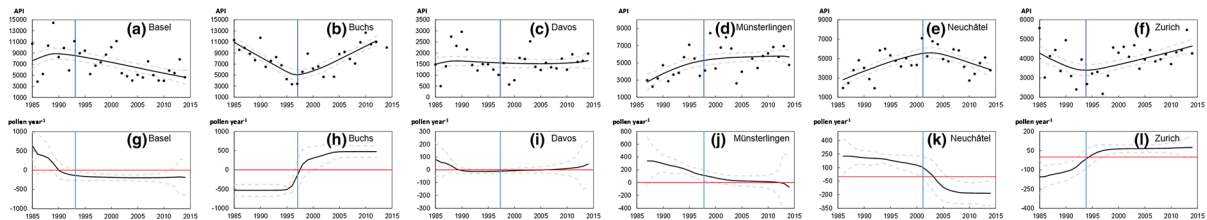


Fig. 5 Model functions for *Poaceae* pollen data in **a** Basel, **b** Buchs, **c** Davos, **d** Münsterlingen, **e** Neuchâtel and **f** Zurich. Black dots: observed API_n, black solid line: estimates of the fit function, grey dashed line: confidence intervals ($\pm$ standard error) around the expectation value, blue vertical line: location

of the change point year. **g–l** Black solid lines show the respective derivative (rates of changes) (pollen year⁻¹) indicating increases (positive values) or decreases (negative values), red line: zero line

4 Discussion

4.1 Bayesian method versus linear models

This study showed that trends derived from different statistical analyses yielded different conclusions about the magnitude and direction of change in airborne pollen concentration. The number of stations that were associated with a negative trend, i.e. with decreases in pollen concentrations, was higher for the change point approach ($N = 7$) than for the linear regression model ($N = 3$). Hence, the choice of the statistical method is of major importance when interpreting aerobiological trends. We argue that the Bayesian change point model has several advantages compared to the linear model since the Bayesian methodology helps to describe important discontinuities and allows a rigorous treatment of uncertainties when determining model and change point probabilities, mean functional behaviours and rates of change (Dose and Menzel 2004).

The detection of change points in aerobiological time series—for *Corylus* between 1999 and 2000, for *Betula* between 1995 and 2004 and for *Poaceae*

between 1994 and 2002—gives rise for major changes and prompts to find explanations for the behaviour of the API_n.

4.2 Causes of changing pollen concentrations

We assessed recent increases, but also decreases of pollen concentrations in Switzerland by applying Bayesian statistics. All cases analysed were associated with increasing concentrations of *Corylus* pollen; however, for *Betula* and *Poaceae* pollen, we only found two and three cases with increasing concentrations, respectively. At single sites, the changes for the three analysed pollen species differed in sign and magnitude.

The average annual temperature in Switzerland increased by 2 °C since 1864, without significant differences between the regions of the analysed pollen traps (MeteoSwiss 2018). Since higher temperatures are linked to higher airborne pollen concentrations, it could be assumed that solely increases in pollen time series can be found. This fact was emphasised by a variety of studies using long-term aerobiological data (e.g. Rasmussen 2002; Spieksma et al. 2003) and

experimental studies focussing on urban–rural gradients as a surrogate for climate change (e.g. Ziska et al. 2003). However, decreases in pollen concentration (e.g. Leuschner et al. 2000; Ugolotti et al. 2015; Fuhrmann et al. 2016) are more difficult to explain in the light of recent climate change. Our study also confirmed that almost 50% of the time series were associated with decreases.

Decreased pollen concentrations were often reported for stations in urban areas, a fact that might be attributed to air pollution and land use changes (Emberlin et al. 1999; Guedes et al. 2009). Our study is based on only one very urbanised monitoring station, Basel (see Table 1 for percentage of artificial surfaces in a 2-km radius). Here, pollen concentrations of birch and grass were indeed associated with decreases but pollen concentrations of hazel with increases. In addition, at some sites, e.g. in urban areas, the physiological performance and thus pollen production of species that are better adapted to colder climates (e.g. birch, spruce) might probably be negatively affected by high temperatures (Clot 2003; Ziello et al. 2012; Jochner et al. 2013). It was also suggested that CO₂ probably exerts an even stronger influence on pollen concentrations than temperature (Ziska et al. 2003; Ziello et al. 2012; Albertine et al. 2014). In addition, little is known about other factors such as nutrients or pollutants. For example, foliar iron concentration along with atmospheric NO₂ concentrations was found to decrease pollen production (Jochner et al. 2013). However, these influential factors could not be investigated in our study.

In addition, site-specific responses found in our study can also be attributed to the general abundance of certain plant species in the immediate surrounding of the pollen trap, growth of the built up area and changes in land use and management. In general, extensive cultivation or planting of (ornamental) trees may increase pollen concentrations at the local scale (Ziello et al. 2012; Gehrig et al. 2015). Grass pollen is believed to be particularly affected by changes in land use (Emberlin 1994; Ghitarrini et al. 2016). In our study, we also found considerable differences in trends for the Poaceae family that could be both enhanced and attenuated by land management. Assuming that grass species prevail in agricultural land, percentage changes of this land cover class (according to CORINE land cover data 1990 and 2012) may explain recent grass pollen trends. These changes are given for

the surrounding 30 km since this area is believed to be the principle pollen catchment area (Newnham et al. 2013). However, these changes were small (see Table 1) varying between − 2.2% (Neuchâtel) and + 4.6% (Zurich) and they were not always linked to similar changes (increases or decreases) in grass pollen concentration (e.g. Zurich). In addition, the area of other land cover classes, where grasses can also be found (Skjøth et al. 2013), changed within this period as well, however, with only maximum values of + 5.9% (increase in artificial surfaces in Zurich; data not shown). Since hazel and birch can occur in or near all five major CORINE land cover categories (artificial surfaces, agricultural area, forest and semi-natural areas, wetlands, water bodies), it may be difficult to establish a link using these data. Quantitative assessments can be better achieved with other inventories (e.g. field surveys or remote sensing data, Skjøth et al. 2013).

Please note that land cover data of 1990 were made available by different datasets for Switzerland [Swiss Federal Statistical Office (SFSO) & Federal Office for the Environment (FOEN) (1998)] and the adjacent European countries (The European Environment Agency 2016a). However, inconsistencies in grouping land cover classes should not affect artificial surfaces and agricultural land [Swiss Federal Statistical Office (SFSO) & Federal Office for the Environment (FOEN) (1998)]. In addition, farming practices have changed during the analysed 30-year period. The intensification of grassland farming led to an increase in cutting frequency from two to three times a year to five times per year today with the first cut long before the flowering of cocksfoot (*Dactylis glomerata*; Bossuyt et al. 2018). On the other hand, the area of extensively managed grassland with cutting dates after the flowering of the grasses has increased and amounts to 12% of the utilised agricultural area (Federal Statistical Office 2015).

4.3 Further influencing factors on allergies

It remains uncertain if the variable considered in our study, the APIn, the annual pollen integral, is the most important measure influencing prevalence rates or whether other factors such as pollen peak values might be more appropriate (Clot 2003). In addition, a risk assessment relying on the actual concentration of airborne pollen does not necessarily reflect the actual

allergy exposure of individuals. The degree to which allergic individuals react with symptoms does not only depend on pollen concentrations but also on the pollen allergen potency, i.e. the amount of allergen per pollen grain (Buters et al. 2012; Jochner et al. 2015). Furthermore, differences in allergen content might also influence the severity and development of allergies (Beggs 2004). However, no long-term data are available which could account for this factor. In addition, qualitative statements are challenging since knowledge about the determinants of pollen allergen potency is largely lacking (Jochner et al. 2015). Further studies would also benefit from regional data on sensitisations which could be linked to aerobiological data.

5 Conclusions

In our study, the trends derived from linear regression analysis differed considerably in magnitude or even in sign compared to the Bayesian modelling results. Therefore, interpreting aerobiological trends should always consider the applied statistical method. In most cases, linear models were not adequate for describing changes in recent pollen concentrations. In addition, the Bayesian change point model is superior in describing discontinuities in our pollen time series. The evolution of pollen concentrations indicates plant- and site-specific differences. Ongoing research should investigate possible influences on atmospheric pollen loads such as climate or land use changes. In addition, further research is required to disentangle the main influential factors, both on pollen concentrations and on prevalence rates of hay fever. This would imply that epidemiological and aerobiological studies are more closely related to each other.

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