A PHENOLOGICAL MODEL TO EVALUATE THE IMPACT OF THE EXPECTED CLIMATE CHANGE ON CUPRESSACEAE MAIN POLLEN SEASON IN CENTRAL ITALY

UN MODELLO FENOLOGICO COME STRUMENTO PER VALUTARE L'IMPATTO DEL ATTESO RISCALDAMENTO GLOBALE SULLA STAGIONE DEI POLLINI DI *CUPRESSACEAE* IN CENTRO ITALIA

Tommaso Torrigiani Malaspina[1]*, Marco Moriondo[2], Marco Bindi[2],
Lorenzo Cecchi[1], Simone Orlandini[1,2]

[1]*Interdepartmental Centre of Bioclimatology, University of Florence, Florence, Italy ADRESSS??????*
[2]*Department of Agronomy and Land Management, University of Florence, Piazzale delle Cascine 18 50144 Florence.*
* *Corresponding author: E-mail: ?????????*

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Abstract

Cupressaceae family has been recognized as a unique source of an increasing number of winter pollinosis in Mediterranean countries. In the area of Florence, Central Italy, cypress (*Cupressus sempervirens*) represents the only source of *Cupressaceae* pollen during winter months. Due to its abundant presence, the concentration of airborne pollen in the area and the impact on allergenic population are dramatically high. It has been well demonstrated that the period of pollination of cypress (Cupressus Main Pollen Season, Cup MPS) shows a high variability year by year, depending on meteorological factors and increasing temperatures as observed in the last 20 years caused an anticipation of Cup MPS in many countries. Accordingly, the aim of the present study is to investigate the effects of the expected global warming on the start date and end date of Cupressaceae MPS in the area of Florence. With this aim, a stochastic weather generator (LARS WG) was run to derive daily Tmin, and Tmax for the present (1990-2006) and future period (2007-2099) (SRES scenario A2). Changes in monthly mean Tmin and Tmax were obtained by HadCM3 General Circulation Model and included in LARS WG for the analysis. Daily Mean T was calculated by Tmin and Tmax simulated by LARS WG and used as input to run the phenological model of male cypress flower proposed by Torrigiani Malaspina *et al.* (2007) for the area of Florence, in order to calculate the MPS of cypress in the next hundred years. The results indicated a progressive anticipation in MPS in 2007-2099 period (from mid February nowadays to mid December at the end of the century). Taking into consideration similar effects of global warming on other allergenic species, present results suggest that the advance of cypress flowering phase could contribute to make allergic season almost all year long in the area under study.

Keywords: Climate Change, Phenology, Pollinosis, Cupressaceae

Riassunto

*La famiglia delle Cupressaceae è stata riconosciuta come unica causa di un numero sempre maggiore di manifestazioni allergiche da polline durante i mesi invernali nei paesi mediterranei. Nella zona di Firenze, centro Italia, il cipresso (*Cupressus sempervirens*) rappresenta l'unica fonte di pollini di* Cupressaceae *durante i mesi invernali. A causa della sua abbondante presenza, la concentrazione di polline aerodisperso nella zone e l'impatto sulla popolazione sensibilizzata sono drammaticamente alti. È stato ampiamente dimostrato che il periodo di dispersione pollini di cipresso (Cupressus Main Pollen Season, Cup MPS) mostra una alta variabilità interannuale legata alle condizioni meteorologiche, e che l'aumento delle temperature osservato negli ultimi 20 anni ha determinato una anticipazione della Cup MPS in molti paesi. Sulla base di queste considerazioni l'obbiettivo di questo ricerca è di analizzare gli effetti che l'atteso riscaldamento globale avrà sulla data di inizio e di fine della Cup MPS nella zona di Firenze. A tal fine sono stati ottenuti i dati giornalieri di temperatura minima e massima per il presente (1990-2006) e per il futuro (2007-2099)(scenario SRES A2) utilizzando un generatore stocastico di serie climatiche (LARS-WG). I cambiamenti attesi per le medie massime e minime mensili sono stati ottenuti dal modello di circolazione globale HadCM3 e inclusi le LARS-WG per l'analisi. Dati di temperatura media giornaliera sono stati calcolati a partire dai dati di Tmin e Tmax simulati dal LARS-WG e usati come input per il modello di simulazione della fenologia maschile del cipresso proposto da Torrigiani Malaspina et al. (2007) per l'area fiorentina, con il fine di calcolare la Cup MPS nei prossimi cento anni. I risultati indicano una progressiva anticipazione della Cup MPS nel periodo 2007-2099 (da metà Febbraio in questo periodo fino a metà Dicembre alla fine del secolo). Prendendo in considerazione simili effetti che il riscaldamento globale atteso avrà su altre specie allergeniche, i risultati presentati suggeriscono che l'anticipazione del periodo di fioritura del cipresso potrebbe contribuire ad allungare per tutti i 12 mesi dell'anno la stagione dei pollini allergenici nell'area di studio.*

Parole chiave: *????????????*

Introduction

The Intergovernmental Panel of Climate Change reported in 2007 that global mean temperature has increased during the 20th century by about 0.6 ± 0.2 °C. Most of the warming has occurred during two periods (1910–1945 and 1976–2000). Many studies showed that as a consequence of this global warming a shifts in plant and animal phenology for the boreal and temperate zones of the northern hemisphere have been occurred (Menzel and Strella, 2001; Sparks and Menzel, 2002; Walther *et al.*, 2002; Parmesan and Yohe, 2003; Root *et al.*, 2003). The phenology is indeed strictly influenced by temperature and in many cases higher temperature have been show to split up plant development (Saxe *et al.*, 2001). In fact plant species require a certain amount of heat to complete their development, and an increase of air temperature may determine a more rapid phenological development, especially in temperate climate. Many authors point out also that in boreal hemisphere early flowering species were most affected by warming changes. This evidence can be justified by the more pronounced increase of temperature in the winter and early spring period (Fitter and Fitter, 2002).

Obviously changes involve also plants producing allergenic pollen, with expected consequences on atopic population (Confalonieri *et al.*, 2007). An earlier start of the pollen season as a consequence global warming was evidenced in studies focused on allergenic plants, as birch, (Emberlin *et al.*, 2002; Van Vliet *et al.*, 2002), mugworth (Stach *et al.*, 2007) Urticaceae (Frenguelli, 2002) , grass (Emberlin *et al.*, 2002, Burr, 1999) and Japanese cedar (Teranishi *et al.*, 2006), even if different methods and different length of datasets were used. Summarizing the most important and significant results we can assume that: many central areas north of the Alps would have longer grass pollen seasons (Emberlin *et al.* 2002); an earlier start and peak of the pollen season is more pronounced in species that start flowering earlier in the year and that the 'duration of the season is extended in some summer and late flowering species' (Huynen and Menne, 2003) i.e. Urticaceae (D'Amato *et al.*, 2002). Also Cupressaceae family seems to be affected by climatic change: Levetin (2001) pointed out an earlier start time for Juniperus pollen significantly related with increase in winter temperatures; Teranishi *et al.* (2000) also found that the first day of the Japanese cedar (*Cryptomeria japonica*) pollen season in Japan advanced over the period 1983–1998, from mid-March to late February.

The influence of climate change on symptoms of respiratory allergy is not easy to predict, but for sure global warming could increase length and severity of pollen season and, as a consequence, of pollinosis.

The IPCC reports also that the global warming is expected to continue to rise at a rapid rate. IPCC guidelines urge not only a reduction of greenhouse gas emission, and a limitation of expected global warming, but also recommend to analysis impact of the expected global warming on ecosystems in order to forecast future evolutions and mitigate negative effects on human life. For this reason many studies has been performed in order to forecast the possible evolutions of allergenic period in next decades.

Cupressus sempervirens, belonging to Cupressaceae family, is an evergreen resinous tree that releases an enormous amount of anemophilous pollen (Belmonte *et al.*, 1999). For this reason, it has been recognized to be responsible for a large part of total annual amount of airborne pollen in several Mediterranean areas. (Ruiz de Calvijo *et al.*, 1988; Mandrioli *et al.*, 2000; Priftanji *et al.*, 2000). Moreover, in last few decades, Cupressaceae pollen has been identified as source of increasing pollinosis in Mediterranean countries such as France (Panzani *et al.*, 1986), Spain (Subiza *et al.*, 1995) and Italy (Caiaffa *et al.*, 1993). It is also responsible for winter pollinosis in a period of the year when no other allergenic plants are flowering (Caramiello *et al.*, 1991; D'Amato e Liccardi, 1994).

The Cupressus genera is not indigenous to Italy, but *C. sempervirens* represents a very important and dominant species in Tuscany, central Italy, and especially in the Florence area. It was introduced by Etruscans and Romans and nowadays its abundance is due both to plentiful reforestations all around the city and successive naturalization, and to ornamental use in parks and graveyards. As a consequence, in atmosphere of Florence cypress airborne pollen concentration reaches several thousand grains/m^3, representing almost the total amount of Cupressaceae pollens during the allergenic period (January-March) (Torrigiani Malaspina *et al.*, 2007).

Accordingly, the aim of the present study is to investigate the effects of the expected global warming on the start date and end date of *Cupressaceae* MPS in the area of Florence, by using phenological model and future climatic scenarios.

Materials and Methods

Study Site

This investigation was performed in the area of Florence, Tuscany region, Central Italy; Florence (λ = 11°11' E; Φ = 43°47' N) is 60 m a.s.l. in a closed valley bottom at the foot of the Apennines, and extends along the plain in a SE-NW direction. It is crossed by the Arno river, and is surrounded by hills to the South and mountains to the North, which rise to almost 1000 m. The area has a climate which can be defined as Mediterranean semi-continental, with cold winters and hot summers. The coldest month is January, with an average temperature of about 6 °C. The warmest months are July and August, with an average temperature of 24 °C.

Study design

With the aim to assess global change impact in the phenology of *C. sempervirens* of this area, the A2 SRES green-house gases emission scenario was choosen from those proposed by IPCC in 2001. The outputs of Tmin and Tmax for the next hundred years of the Canadensis General Circulation Model (namely HADCM3) on the basis of A2 SRES ([CO2]= 700 ppm in 2100) was used. Because of the very low horizontal resolution of outputs of GCM, Tmin and Tmax were downscaled using the stochastic weather generator LARS WG (Semenov and Barrow, 1997). Finally daily mean temperature (Tmean) was calculated and used as input variables of a phenological model able to simulate male cypress phenology.

Fig. 1 – Tuscany regional meteorological station network
Fig. 1 *– Rete delle stazioni meteorologiche della Toscana)*

Meteorological data and downscaling technique

In this study, the synthetic meteorological data for the period 1990-2099 are the result of a GCM statistical downscaling, using LARS-WG approach, over an existing regional meteorological network. This network (Fig. 1) consists of 119 weather stations, located in Tuscany region, with daily values of minimum and maximum temperature, over relatively long periods (15 and 20 yr) included between 1985 and 2005.

According to LARS WG procedure to reproduce present local climate (Semenov and Barrow, 1997), available observed daily weather for a given site was used to determine a set of parameters for probability distribution of weather variables as well as correlations between them. This set of parameters was then used to generate both the synthetic weather time series describing the present period and as a baseline to be perturbed according the result of GCM. For the former, 15 years were produced as reference for the present period. As concerning the latter, the results of the HadCM3 GCM, were used as forcing factors in the downscaling procedure. Moreover A2 ([CO2]= 700 ppm in 2100) green-house gases emission scenarios was selected among those proposed by SRES (IPCC, 2001). So for the HadCM3 GCM and A2 SRES scenarios, 1990-2099 daily Tmin and Tmax serie were extracted from nearest grid cell to Tuscany region. Each time series was then split in 4 sub-set data called respectively present period (1990-2005), future period 1 (2006-2036), future period 2 (2037-2068), future period 3 (2069-2100). The forcing factors for each future period, as required by LARS WG, were computed as monthly average respect to the reference period (1990-2005). For temperature the relative change in standard deviation and in duration of wet and dry spell were also calculated.

Observed meteorological data

In order to confront simulated data obtained as previously described with observed data, daily Tmin an Tmax (°C), for the period 1990-2005, were obtained from the weather station located in Florence (70 m. asl, Coordinate Gauss-Boaga x: 1681423 y: 4849368) and in Barberino di Mugello (406 m. asl, Coordinate Gauss-Boaga x: 1682069 y: 4875275) and managed by the Agenzia Regionale per lo Sviluppo e l'Innovazione nel Settore Agricolo-forestale (ARSIA). Monthly mean values were calculated for whole period. The two weather stations were selected in the area of study, among those that form the regional network used in the downscaling process. The choice of Florence and Barberino di Mugello stations is due to the fact that the two stations are located respectively in the lower part (60 m asl) and in the higher part (400 m asl) of the area of study.

Phenological Model

The model adopted to simulate the evolution of Cupressaceae Main Pollen Season (Cup MPS) in next hundred years is the one proposed by Torrigiani Malaspina (2007). The model were build on the basis of phenological observation in different climatic conditions and validated on the basis of historical aerobiological data-set (six years). The model is based on the Growing Degree Days accumulation (GDD) and it is able to simulate the phenological development of male flower of *C. sempervirens* on the basis of the daily mean temperature from first October to the end of flowering period. The values of GGD index with threshold of 0 °C needed from 1 October to reach the starting (SD) and ending (ED) of Cup MPS result respectively 1386.2 °C and 1576.9 °C (Torrigiani Malaspina *et al.*, 2007).

The model is nowadays operatively utilized to forecast SD and ED of the Cup MPS for the provincial district of Florence. Because of the methodology adopted to build the model, the Cup MPS predicted by the model is the period included between the days when the concentration of Cupressaceae pollen in the air reaches respectively the 12.5 % and the 87.5% of total annual count of Cupressaceae pollen concentration.

As the model was build and validated in the area of Florence, in this study its application will be limited to this area.

Tmean data obtained as mean value between Tmin and Tmax for the present and for the three future periods were utilized to run the phenological model. The input of the model is represented by the accumulation of GDD with threshold of 0 °C from 1 October to SD and ED of Cup MPS. Output of the model is represented by SD and ED of Cup MPS for the present and for the three future periods.

Results and discussion

Expected increase of temperature in Tuscany on the basis of SRES A2 scenario.

Fig 2 shows the Annual Mean Temperature for the present (1990-2005) and for three future periods (2006-2036, 2037-2068 and 2069-2100), as it resulted by the

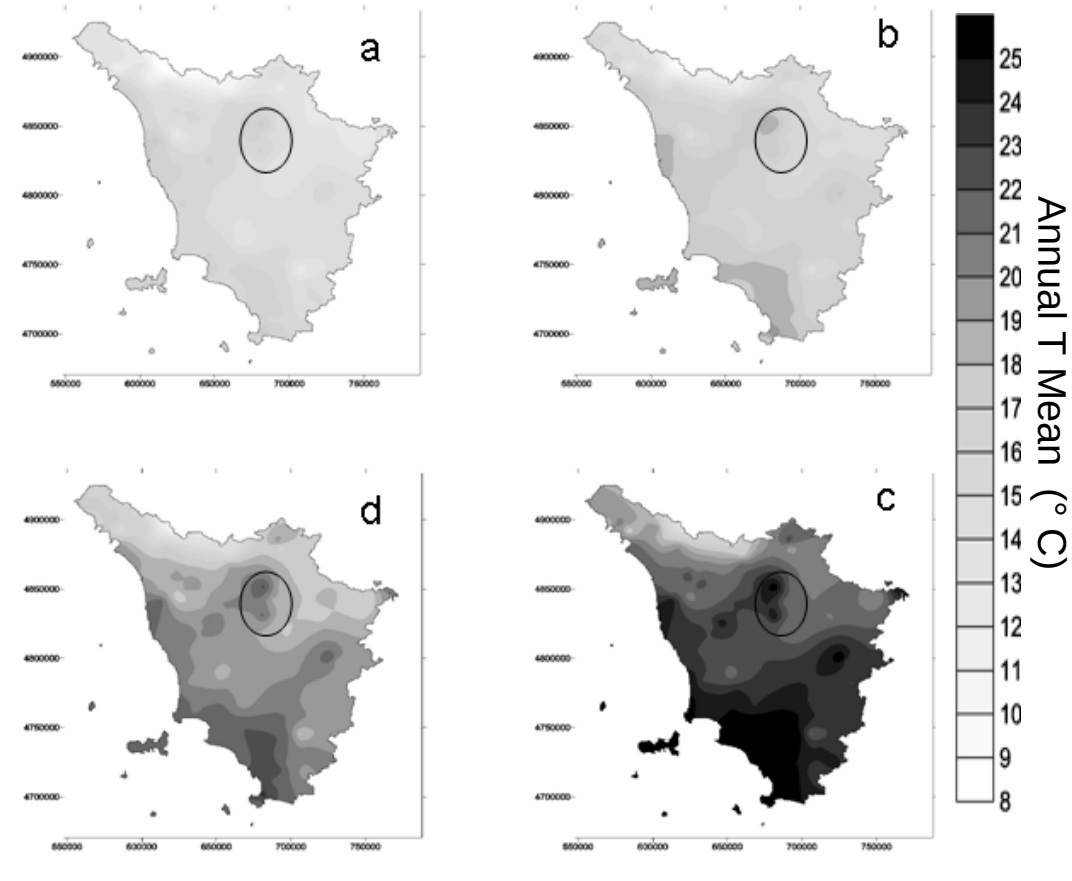

Fig. 2 – Tuscany Annual Mean Temperature for the present (a-1990-2005) and for three future periods (b-2006-2035, c-2036-2067 and d-2068-2100), as it resulted by the downscaling technique on the basis of HAD CM3 GCM and A2 SRES scenario. Ringed area represents the area of validity of the model

Fig. 2 *– Temperatura Media Annuale in Toscana per il presente (a-1990-2005) e per i tre periodi futuri (b-2006-2035, c-2036-2067 and d-2068-2100), ottenuti con la tecnica di downscaling sulla base dei dati del modello di circolazione globale HAD CM3 GCM e scenario SRES A2. La zone cerchiata rappresenta l'aria di validità del modello*

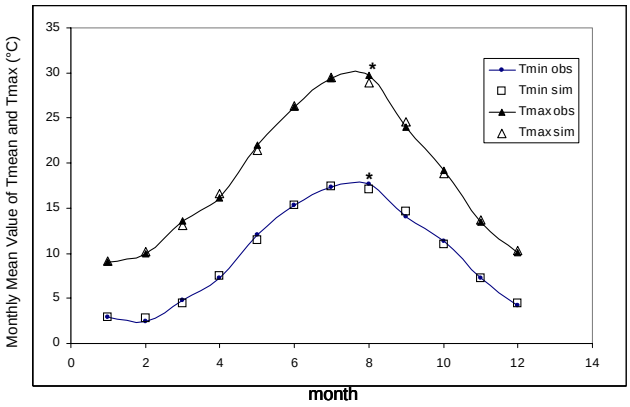

Fig 3 - Monthly mean value of Tmin and Tmax in Barberino di Mugello vs. monthly mean Tmin and Tmax simulated in the higher part of the area of study for the present period. Only August values show statistical differences (*)

Fig 3 *- Tmin e Tmax media mensile a Barberino di Mugello vs. Tmin e Tmax media mensile simulata nella parte più elevata dell'area di studio per il presente. Solo i valori relativi a Agosto mostrano differenze significative (*)*

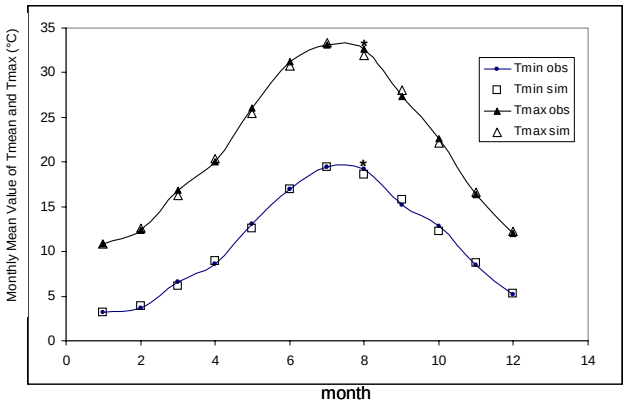

Fig 4 -Monthly mean value of Tmin and Tmax in Florence vs. monthly mean Tmin and Tmax simulated in the lower part of the study area for the present period. Only Augost values show statistical difeerences (*)

Fig 4 *- Tmin e Tmax media mensile a Florence vs. Tmin e Tmax media mensile simulata nella parte più elevata dell'area di studio per il presente. Solo i valori relativi a Agosto mostrano differenze significative (*)*

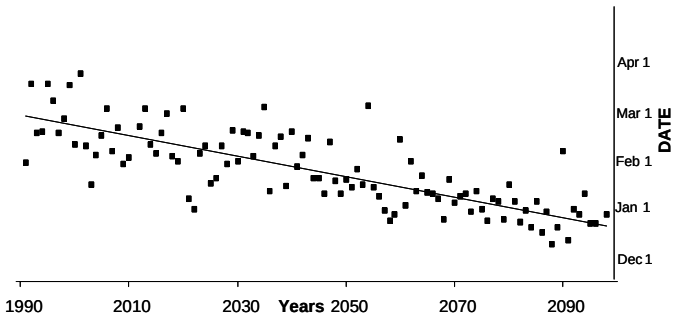

Fig. 5 – Simulated SD of Cup MPS vs years in the period 1990-2100

***Fig. 5** – SD della Cup MPS simulata vs anni nel periodo 1990-2100*

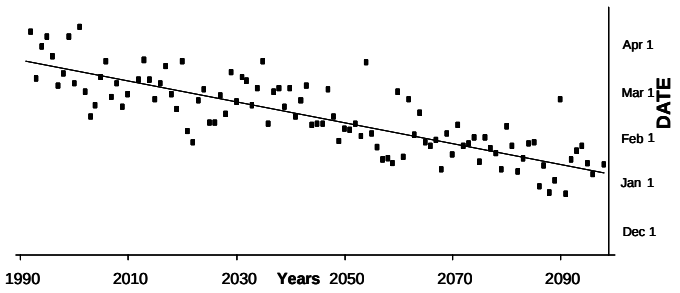

Fig. 6 – Simulate ED of Cup MPS vs years in the period 1990-2100

***Fig. 6** – ED della Cup MPS simulata vs anni nel periodo 1990-2100*

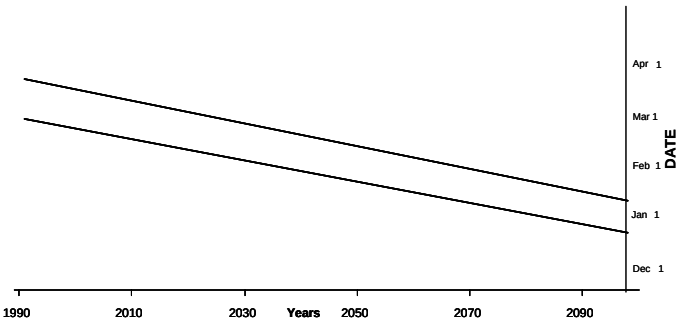

Fig. 7 – The area between the lines represents simulated Cup MPS vs years in the period 1990-2100

***Fig. 7** – L'area compresa tra le linee rappresenta la Cup MPS simulata vs anni nel periodo 1990-2100*

downscaling technique on the basis of HADCM3 and A2 SRES scenario. Annual Mean Temperature in the area of Florence is expected to increase from the actual range of 17-18 °C to 22-23 °C at the end of the century.

Daily Tmean for the same periods were obtained to be used as input to run the phenological model. Temperature data were obtained for the whole regional area of Tuscany, but only data concerning the area of Florence were used as input of the model.

IPCC SRES scenarios provides very useful information to evaluate possible impact of expected global warming on environment. Unfortunately scenarios are generated by GCM that are characterized by a very low horizontal resolution (CGM grids are 250X250 Km). As a consequence data are inadequate to be used a regional or local level. Thank to the LARS-WG downscaling technique, a Daily Mean Temperature data series useful to evaluate expected global warming at local level was obtained. These data can be used as input of the phenological model to evaluate expected global warming impact on Cup MPS in the area of the study.

Comparison between simulated and observed data

Monthly mean values of Tmin and Tmax for the present period obtained as previously described were statistically confronted with data registered by the weather stations of Florence and Barberino di Mugello. Extreme (maximum and minimum) values of Tmin and Tmax were choosen for this aim from those obtained in the study site. Maximum and minimum value were statistically confronted with Florence and Barberino di Mugello data respectively (Fig 3 and 4).

In both cases, only August mean value shows statistical differences between simulated and observed data. No statistical differences resulted for monthly mean values from October to March, period that contain the whole set of data needed to run the phenological model.

As a consequence observed and simulated data resulted statistically identical over a long period (i.e. 15 years), and simulated data can be fruitful used to run the phenological model in order to simulate male cypress phenology evolution on the basis of expected global warming.

Simulation of the phenology for the future

Fig 5 shows SD of Cup MPS in Florence from 1990 to 2100 simulated by the model using as input stochastically downscaled Tmean provided by HadCM3 GCM on the basis of A2 SRES. The plot shows a clear progressive anticipation of SD from the second part of February in the present period to the second part of December at the end of the century.

Also simulated ED shows a progressive anticipation of almost two months in next hundred years (Fig 6). Consequently Cup MPS in Florence will have a progressive anticipation in the same period of almost two months (Fig 7).

Mean value of SD and ED of Cup MPS for the present period (1990-2005) and for the three future periods (2006-2036; 2037-2068; 2069-2100) were also calculated in five points of the study area. The five points were selected in correspondence of the weather stations belonging to the network of stations used in the downscaling procedure (the weather stations of Firenze, Galceti, Greve, Tavarnelle and Barberino di Mugello)(Tab 1). The mean values of SD and ED of Cup MPS for the four periods were also obtained for several points of the study area. Date were interpolated each others in order to obtain

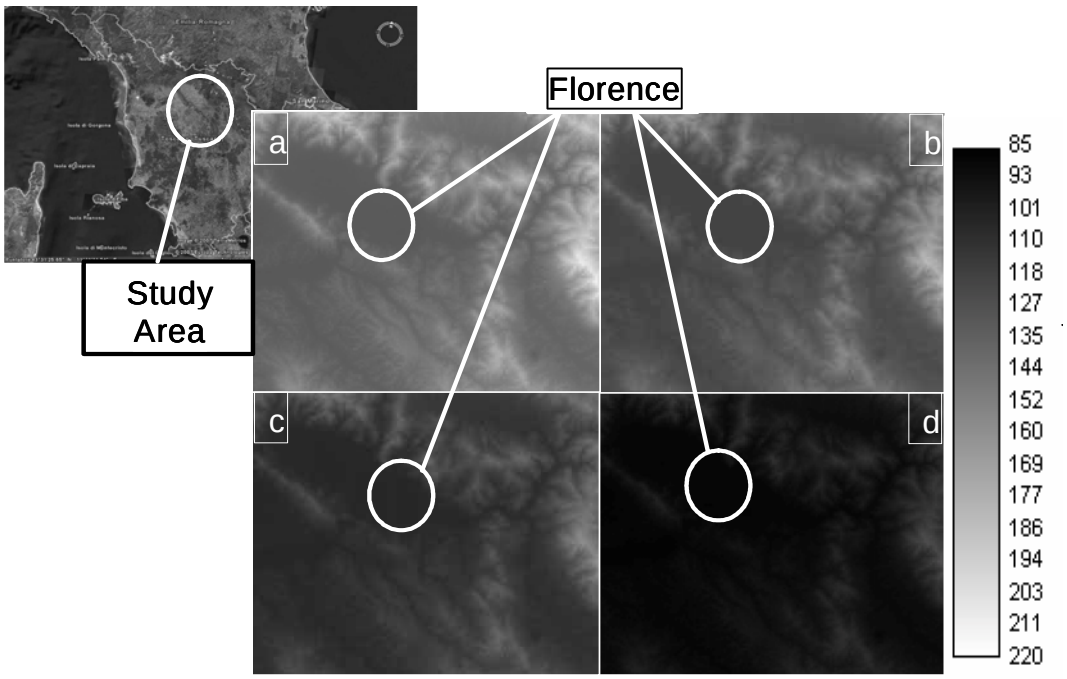

Fig. 8 – SD of Cup MPS in the area of Florence simulated by the model in the periods 1990-2005 (a), 2006-2036 (b), 2037-2968 (c) and 2069-2100 (d)

Fig. 8 *– SD della Cup MPS nell'areae di Firenze simulata dal modello nei periodi 1990-2005 (a), 2006-2036 (b), 2037-2968 (c) and 2069-2100 (d)*

a mean value for the four periods of SD (Fig 8) and ED of Cup MPS spatialized in the whole area.

Conclusion

Cypress allergy is of great importance in some Mediterranean areas and its prevalence seems to demonstrate an upward trend also in other regions, concomitantly with the increased use of cypress trees as ornamental plants, as wind breaks and as hedges. (Charpin, 2005). In central Italy, the prevalence of skin prick test positivity increased from 7.2% in 1995 to 22% in 1999. (Papa *et al.* 2001). For these reasons, a prediction about features of cypress flowering periods in the next decades might be important to evaluate possible effects on allergic patients. Present findings suggest a shift toward an earlier flowering season of cypress in the area of Florence.

The overall impact on people allergic to cypress pollen is difficult to predict. Since patients are mainly sensitized to more than one pollen, it is arguable that the effects of climate change on the other allergenic plants will be of great importance. In addition, some data show a specie-specific response to environmental changes, including temperature increase (Emberlin *et al.* 1999). If global warming will affect the flowering period of main allergenic species in the same way, present results suggest that the advance of cypress flowering phase could contribute to make allergic season much longer and dangerous for allergic population.

References

Belmonte, J., Canela, M., Guardia, R., Sbai, L., Vendrell, M., Cariñanos, P., Diaz de la Guardia, C., Dopazo, A., Fernandez, D., Gutierrez, M., Trigo, M.M., 1999. Aerobiological dynamics of the cupressaceae pollen in Spain, 1992-98. Polen, 10,27-38

Burr, M.L., 1999. Grass pollen: trends and predictions. Clin Exp Allergy, 29,735-738

Caiaffa, M.F., Macchia, I., Strada, F., Bariletto, G., Scarpelli, F., Tursi, A., 1993. Airborne Cupressaceae pollen in southern Italy. Ann Allergy, 71, 45-50

Caramiello, R., Gallesio, M.T., Siniscalco, C., Leone, F., 1991. Aerobiological data and clinical incidence in urban and extra urban environments. Grana, 30, 109-112

Charpin, D., 2005. Allergy to cypress pollen. Allergy, 60, 293-301

Confalonieri, U., Menne, B., Akhtar, R., Ebi, K.L., Hauengue, M., Kovats, R.S., Revich, B., Woodward, A., 2007. Human health. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergov-

Tab. 1- Simulated SD and ED of Cup MPS (numbers of days from 1st October) calculated in five points of the study area, for the present and for the three future periods

Tab. 1 *- SD e ED simulati della Cup MPS (numero di giorni dal 1° ottobre) calcolati in cinque punti dell''area di studio per il presente e per i tre periodi futuri*

		1990-2005		2006-2036		2037-2068		2069-2100	
	m asl	SD	ED	SD	ED	SD	ED	SD	ED
Firenze	60	122	143	112	131	99	117	84	101
Galceti	80	141	162	128	149	113	134	93	115
Greve	300	162	181	144	167	125	149	102	124
Tavarnelle	358	145	169	131	154	117	138	96	117
Barberino	400	145	168	131	153	115	136	94	115

ernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 391-431

D'Amato, G., Licciardi, G., 1994. Pollen-related allergy in European Mediterranean area. Clin Exp Allergy, 24, 210-219

D'Amato, G., Liccardi, G., D'Amato, M., Cazzola, M., 2002. Outdoor air pollution, climatic changes and allergic bronchial asthma. Eur Respir J, 20, 763–76

Emberlin, J., Mullins, J., Corden J., Jones, S., Millington, W., Brooke, M., Savage, M., 1999. Regional variations in grass pollen seasons in the UK, long-term trends and forecast models. Clin Exp Allergy, 29(3), 347-56

Emberlin, J., Detandt, M., Gehrig, R., Jaeger, S., Nolard, N., Rantio-Lehtimäki, A., 2002. Responses in the start of Betula (birch) pollen seasons to recent changes in spring temperatures across Europe. Int J Biometeorol, 2002, 46, 159–170

Fitter, A.H., Fitter, R.S.R., 2002. Rapid changes in flowering time in British plants. Science, 296, 1689-1691

Frenguelli, G., 2002. Interactions between climate changes and allergenic plants. Monaldi Arch Chest Dis, 57(2), 141-143

Huynen, M., Menne, B., 2003. Phenology and human health: allergic disorders. Report of a WHO meeting, Rome, Italy, 16–17 January 2003. Health and global environmental change, Series No. 1. (EUR/03/5036791 and EUR/02/5036813)

IPCC, 2001. Climate change 2001: the scientific basis. In: Third Assessment report of the Working Group I (eds Houghton, J.T. et al.), Cambridge University Press, Cambridge

Levetin, E., 2001. Effects of climate change on airborne pollen. J Allergy Clin Immunol, S107:S172.

Mandrioli, P., De Nuntiis, P., Ariatti, A., Magnani, R., 2000. Cypress in Italy: landscape and pollen monitoring. All Immunol, 31, 116-121

Menzel, A., Estrella, N., 2001. Plant Phenological Changes, In 'Fingerprints' of Climate Change – Adapted Behaviour and Shifting Species Ranges. eds Walther, G.R., Burga, C.A., Edwards, P.J., pp. 123–137

Panzani, R., Centanni, G., Brunel, M., 1986. Increase of respiratory allergy to the pollens of cypress in the south of France. Ann Allergy, 56, 460-463

Papa, G., Romano, A., Quarantino, D., Di Fonso, M., Viola, M., Artesiani, M.C., Sernia, S., Di Gioacchino, M., Venuti, A., 2001. Prevalence of sensitization to Cupressus sempervirens: a 4-year retrospective study. Sci Total Environ, 10, 270(1-3), 83-7

Parmesan, C., Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421, 37–42.

Priftanji, A., Gjebrea, E., Shkurti, A., 2000. Cupressaceae in Tirana (Albania) 1996–1998: aerobiological data and prevalence of Cupressaceae sensitization in allergic patients. All Immunol, 31, 122–124

Root, T.L., Price, J.T., Hall, K.R. 2003. Fingerprints of global warming on wild animals and plants. Nature, 421, 57–60.

Ruiz de Calvijo, E., Galan, C., Infante, F., Dominguez, E., 1988. Variations of airborne winter pollen in Southern Spain. Allergology et Inmunology, 16, 175- 179

Semenov, M.A., Barrow, E.M., 1997. Use of a stochastic weather generator in the development of climate change scenarios. Climatic Change, 35, 397-414

Saxe H, Cannell MGR, Johnsen B, Ryan MG, Vourlitis G. 2001. Tree and forest functioning in response to global warming. New Phytologist 149: 369–399.

Sparks, T.H., Menzel, A. 2002. Observed changes in seasons: an overview. Journal of Climatology, 22, 1715–1725.

Stach, A., García-Mozo, H., Prieto-Baena, J.C., Czarnecka-Operacz, M., Jenerowicz, D., Silny, W., Galán, C., 2007. Prevalence of Artemisia Species Pollinosis in Western Poland: Impact of Climate Change on Aerobiological Trends, 1995–2004. J Investig Allergol Clin Immunol. 17(1), 39-47

Subiza, J., Jerez, M., Jimenez, J.A., Narganes, M.J., Cabrera, M., Varela, S., Subiza, E., 1995. Allergenic pollen pollinosis in Madrid. J Allergy Clin Immunol, 96, 15-23

Teranishi, H., Kenda, Y., Katoh, T., Kasuya, M., Oura, E., Taira, H., 2000. Possible role of climate change in the pollen scatter of Japanese cedar Cryptomeria japonica in Japan. Climate Research, 14, 65–70

Teranishi, H., Katoh, T., Kenda, K,. Hayashi, S., 2006. Global warming and the earlier start of the Japanese-cedar (Cryptomeria japonica) pollen season in Toyama, Japan. Aerobiologia, 22, 91–95

Torrigiani Malaspina, T., Cecchi, L., Morabito, M., Onorari, M., Domeneghetti, M.P., Orlandini, S., 2007. Influence of Meteorological Conditions on Male Flower Phenology of Cupressus Sempervirens and Correlation with Pollen Production in Florence. Trees, 21(5), 507-514

Van Vliet, A.J.H., Overeem, A., De Groot, R.S., Jacobs, A.F., Spieksma F.T.M., 2002. The influence of temperature and climate change on the timing of pollen release in the Netherlands. Int. J. Climatol., 22, 1757–1767

Walther, G.R., Post, E., Convey, P., 2002. Ecological responses to recent climate change. Nature, 416, 389–395