Adaptación varietal y cambio climático en olivo:
del reposo invernal a la floración

Influence of Climate Change on Olive Reproductive Phenology in the Mediterranean area: trends and modeling

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Botany

Palynology

Epidemiology

Meteorology

Phenology

Aerobiology

Agronomy

Phytopathology

Micology

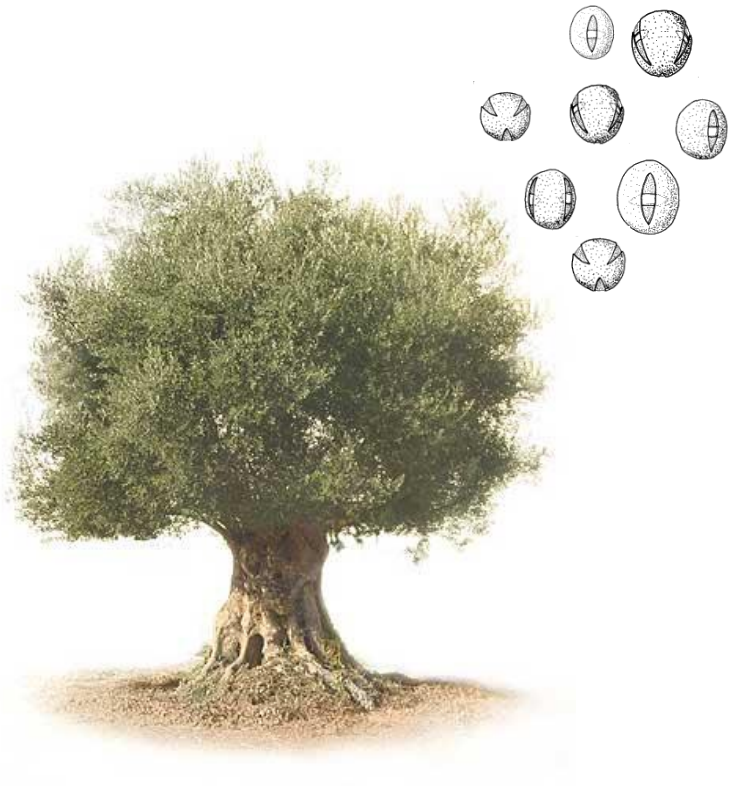
Medicine

Ecology

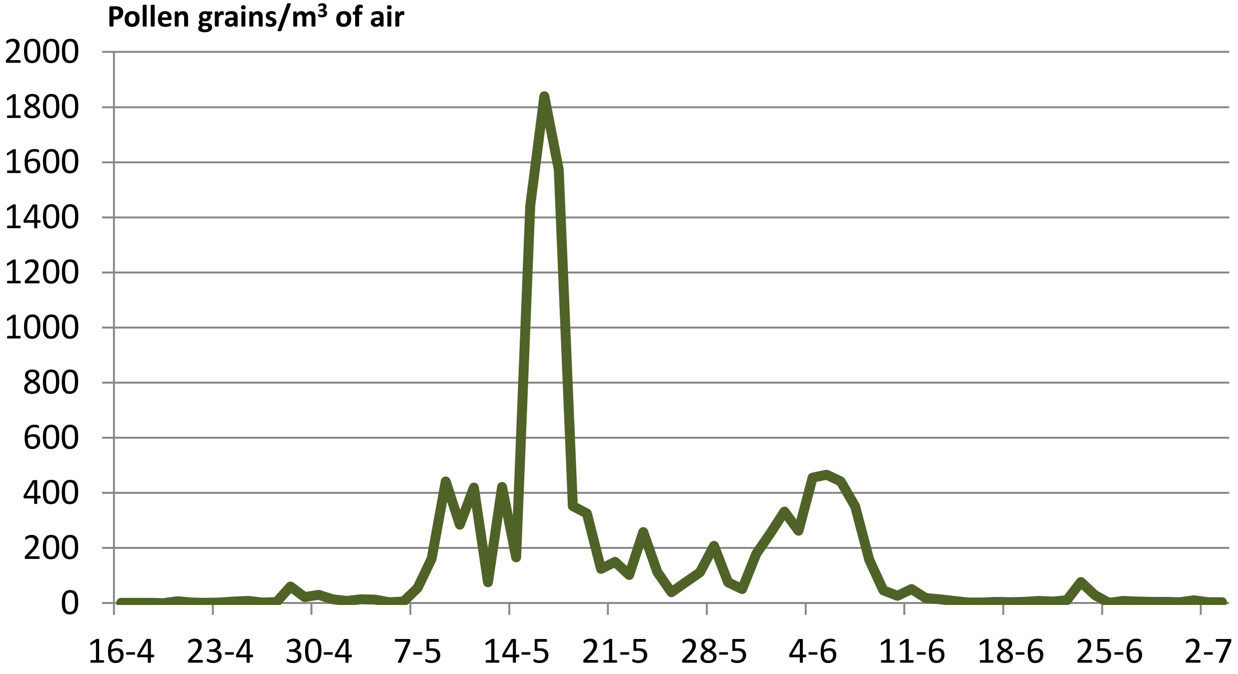
Forensic Sciences

Genetic

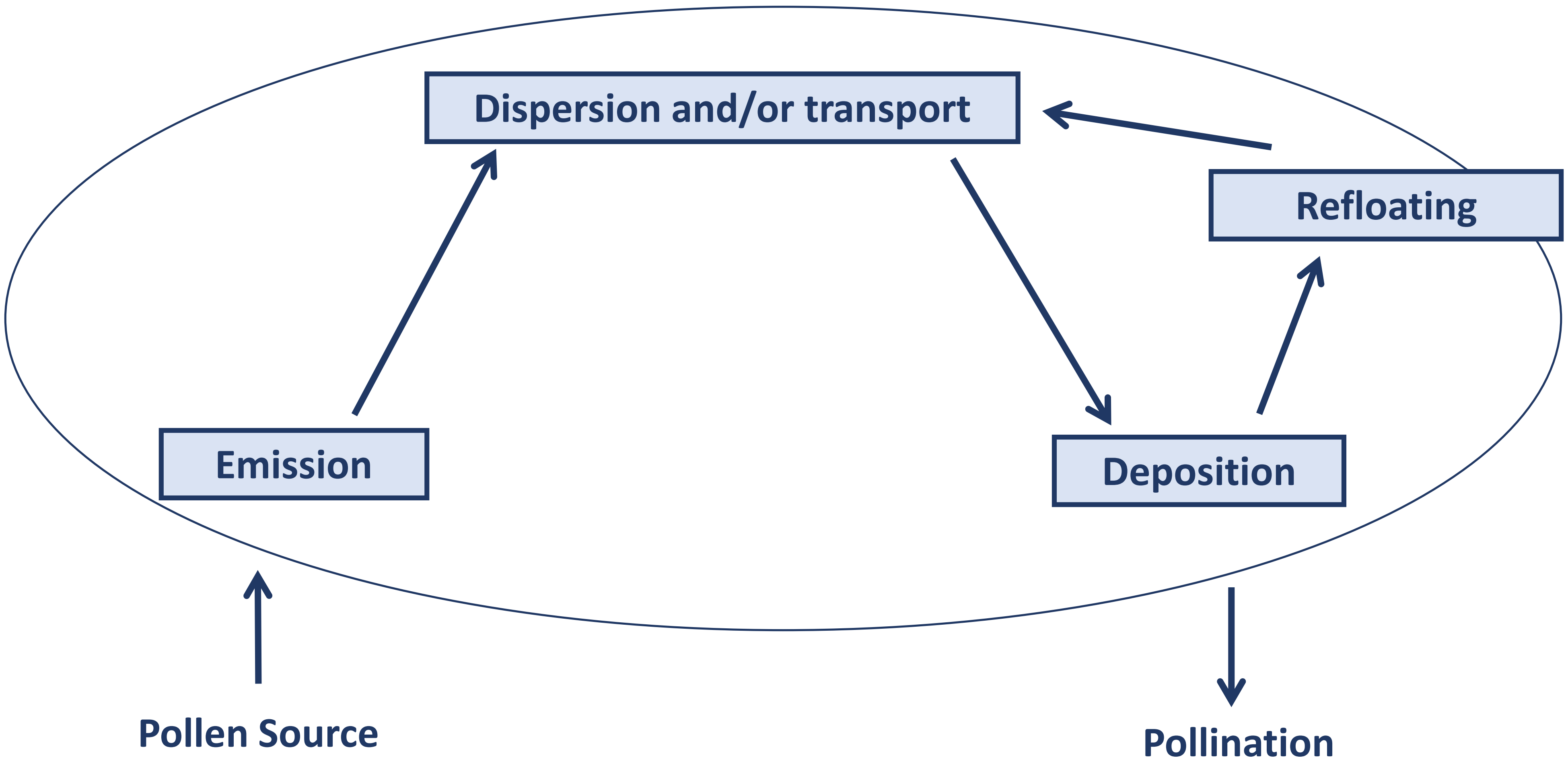
Science that study the airborne microorganisms and biological particulate matter, i.e. pollen or spores



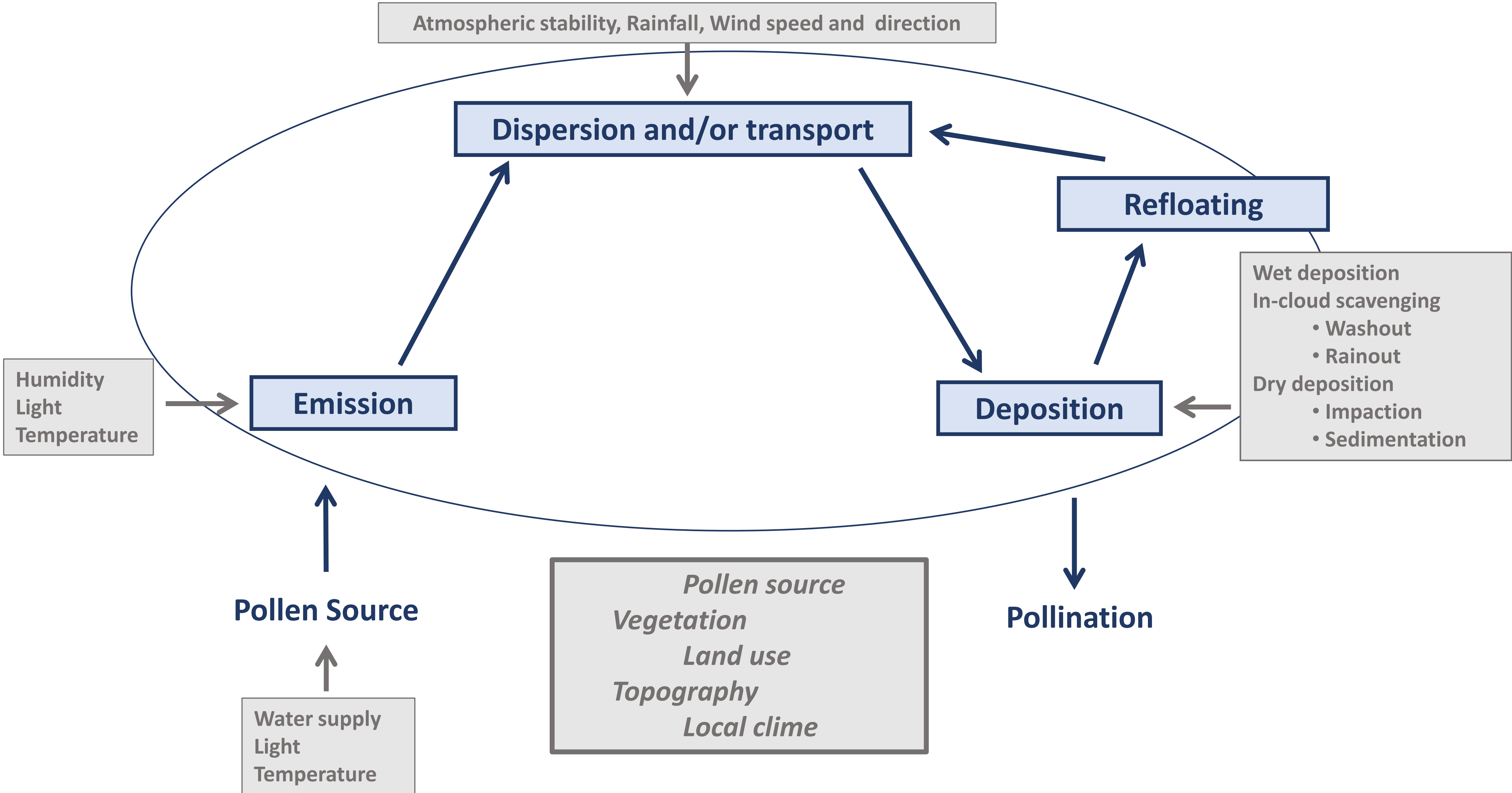
Airborne Olive Pollen



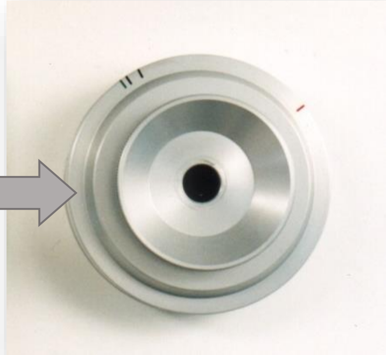
Aerobiological Processes

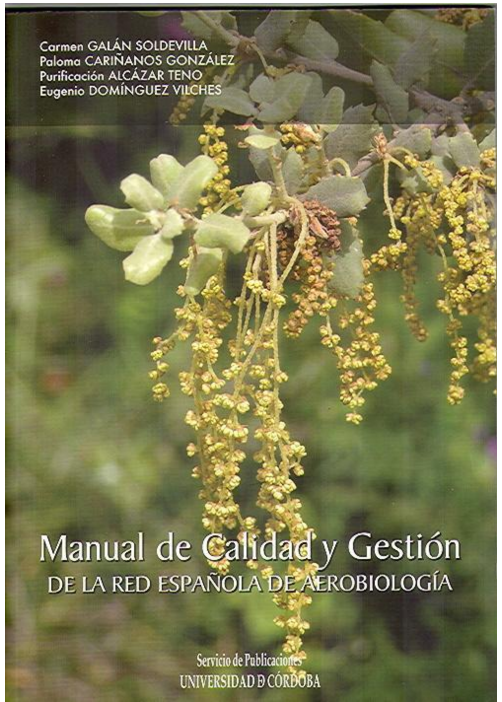


Aerobiological Processes



Spanish Aerobiology Network





Aerobiologia (2014) 30:385–395
DOI 10.1007/s10453-014-9335-5

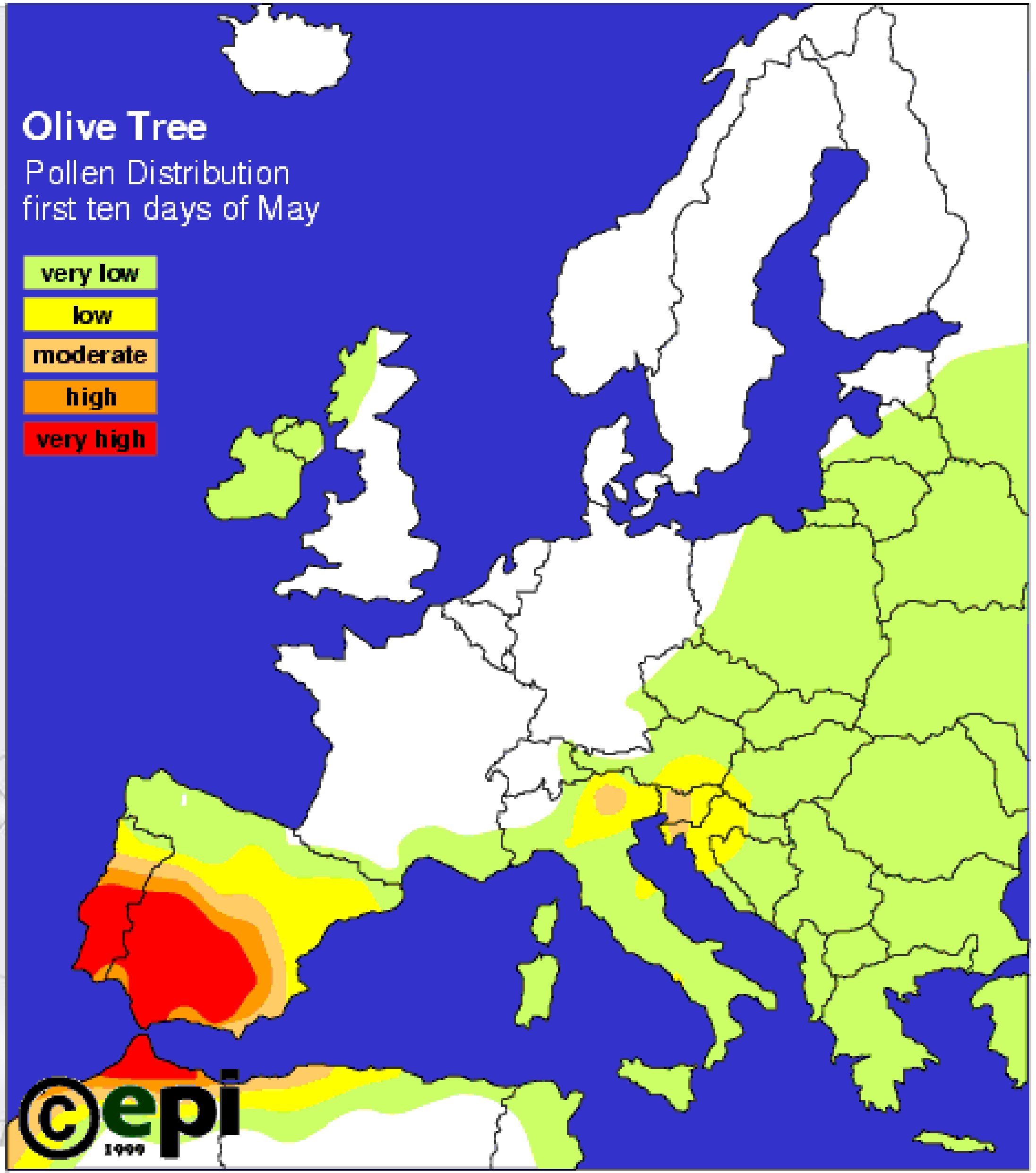
ORIGINAL PAPER

Pollen monitoring: minimum requirements and reproducibility of analysis

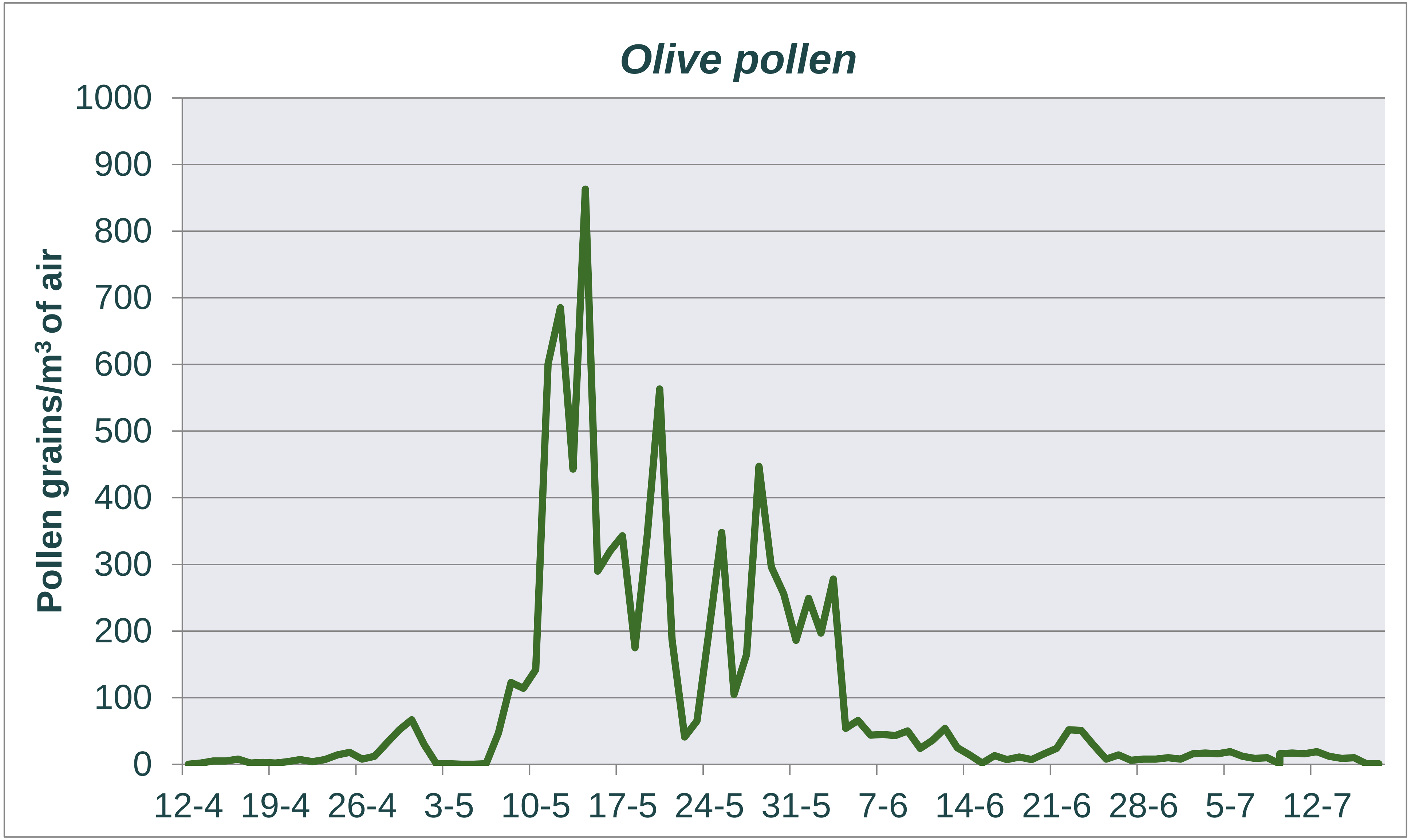
C. Galán · M. Smith · M. Thibaudon · G. Frenguelli · J. Oteros · R. Gehrig · U. Berger · B. Clot · R. Brandao · EAS QC Working Group

EAN
European Aeroallergen Network

Polleninfo.org



Airborne Pollen



Today airborne pollen is considered as a measure of flowering phenology in anemophilous plants, offering information on both flowering timing and intensity

Reproductive Phenology

Growth stages of mono-and dicotyledonous plants, BBCH- scale

*Biologische **B**undesanstalt, **B**undessortenamt und **CH**emische Industrie (BBCH)*

- General Scale
- Cereals, Rice, Maize
- Oilseed rape, Faba bean, Sunflower
- Beta beets
- Potato
- Fruits
- Citrus, Olive, Coffee, Banana
- Grapevine
- Soybean, Cotton, Peanuts
- Hop
- Vegetable crops I
- Vegetable crops II
- Weeds

BBCH- scale , a system for a uniform coding of phenological similar growth stages of all mono- and dicotyledonous plant species

Meier U Ed. 1997. *Growth stages of mono-and dicotyledonous plants*. BBCH Monograph. Federal Biological Research Centre for Agriculture and Forestry. Berlin.
Meier et al. 2009. *Journal Für Kulturpflanzen*, 61(2):41–52

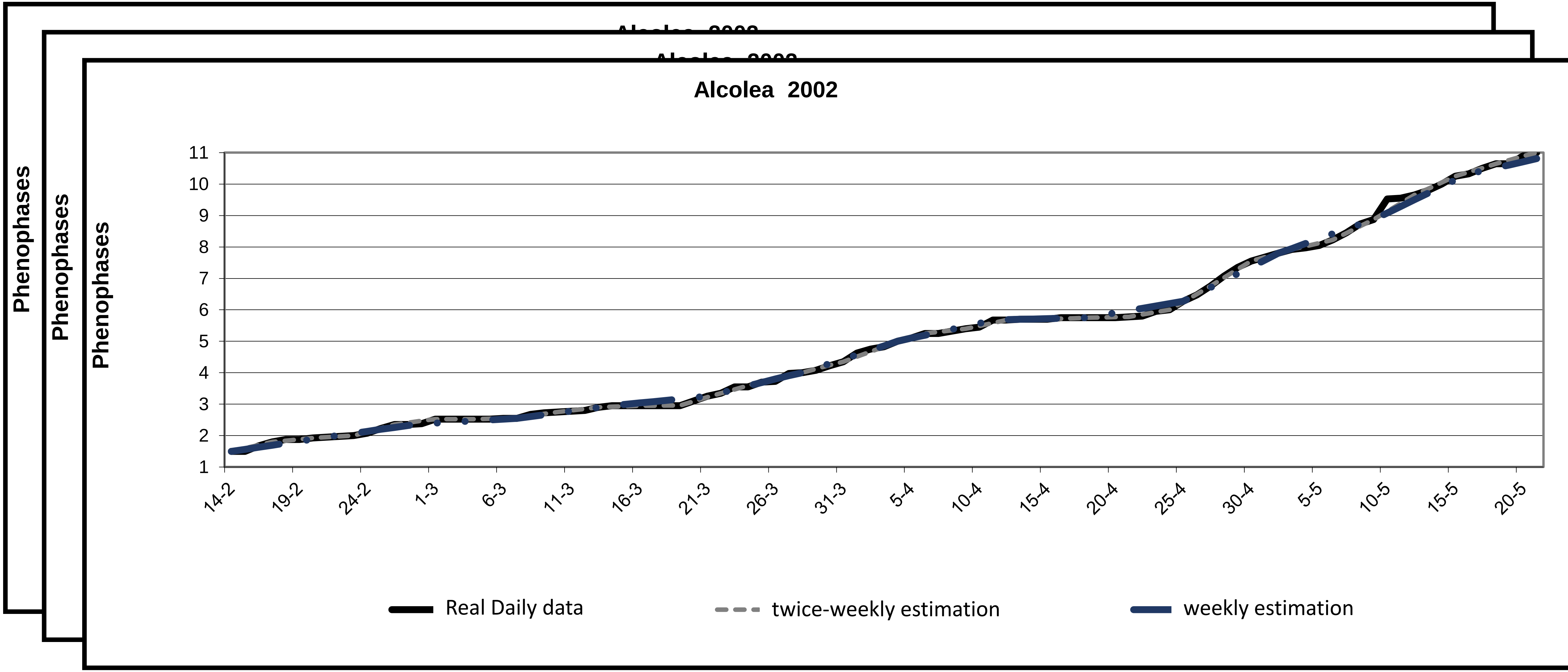
Growth Stages

Phenological development of Olive flowering, following BBCH standard scale. a-50, b-51, c-54, d-57, (<15% open flowers); f-65, (>15% open flowers); g-67, (<15% open flowers); h-68

Oteros et al 2013. *Agriculture,Ecosystems and Environment*, 179:62– 68

Optimal frequency of phenological observations

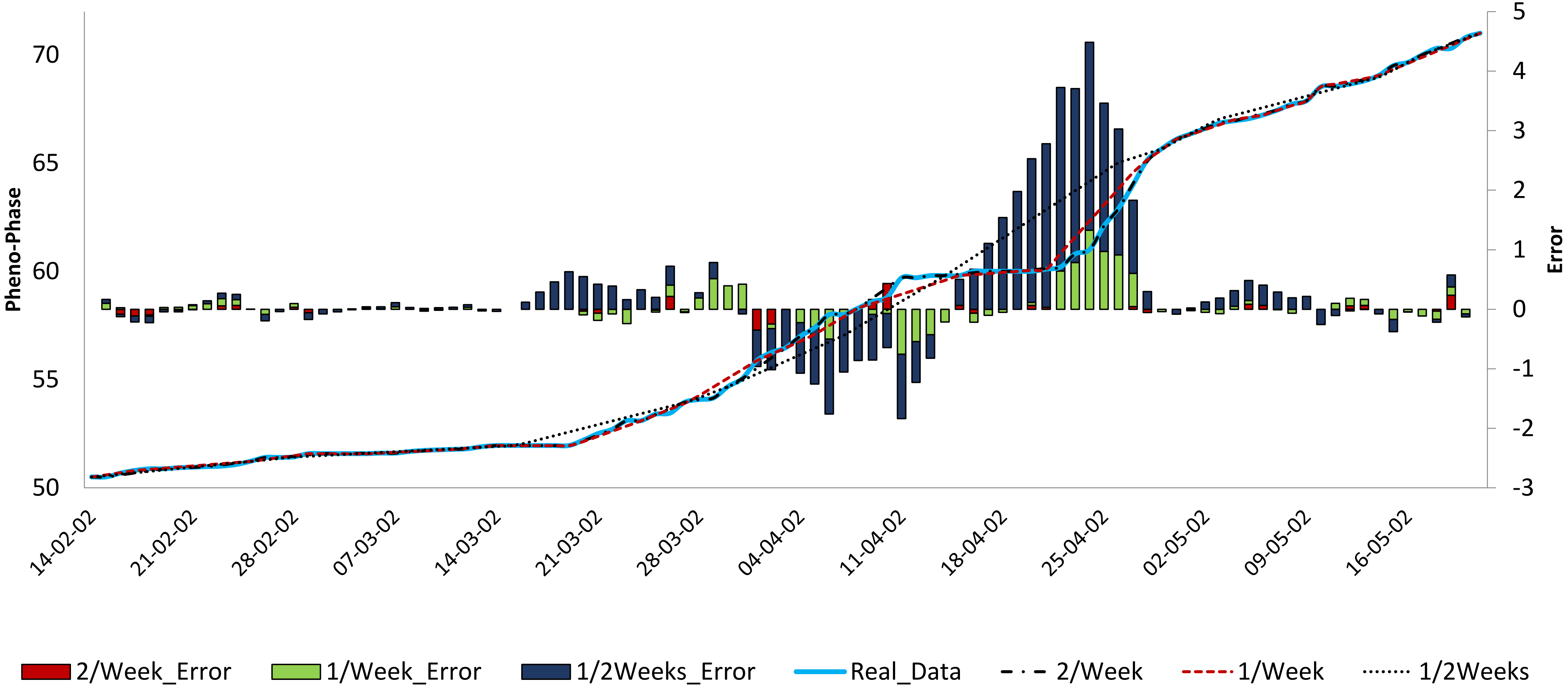
1. What is the optimal frequency of phenological observations during the reproductive period?



Oteros et al 2013. *Agriculture, Ecosystems and Environment* 179:62– 68

Optimal frequency of phenological sampling

2. Can we estimate daily data by linear interpolation?

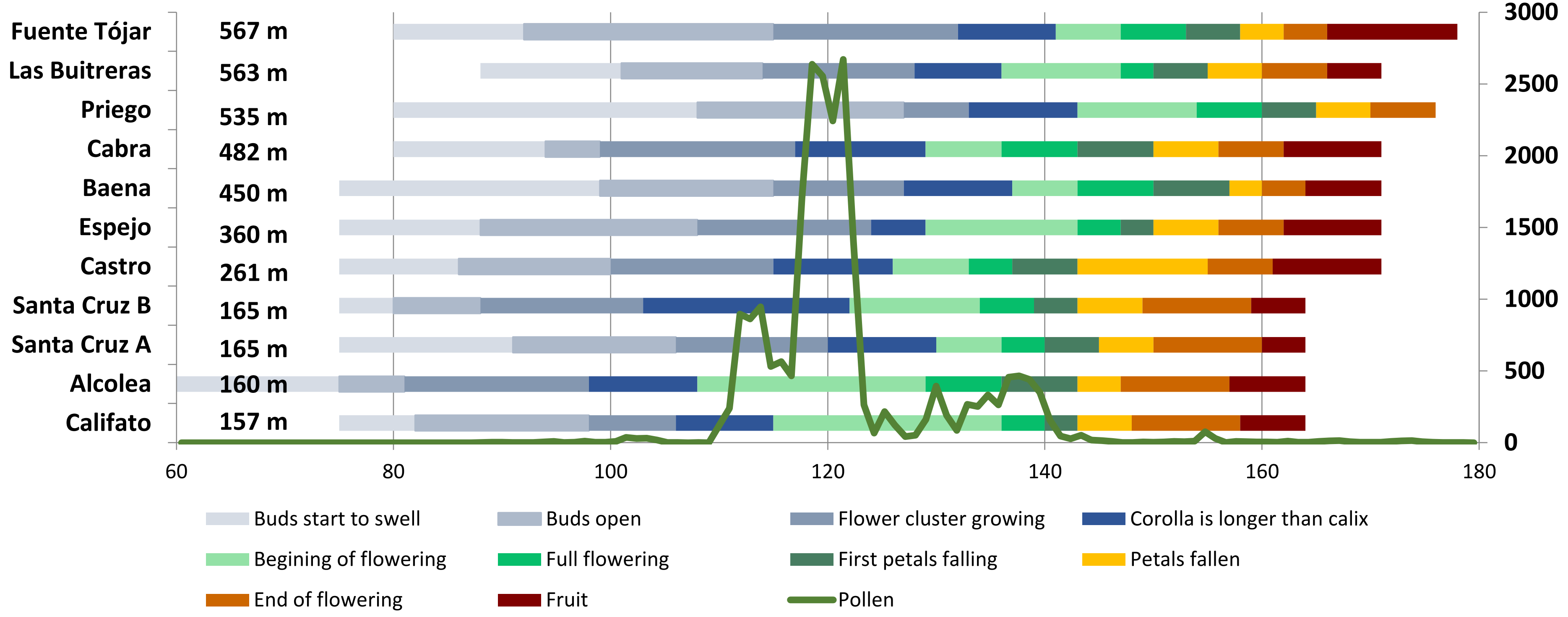


Weekly observations was deemed to be accurate and daily data can be estimated

Oteros et al 2013. *Agriculture, Ecosystems and Environment* 179:62– 68

Phenology and Topography

Which olive population more contribute to the pollen curve?



Olive in Córdoba

Airborne pollen represents flowering phenology of olive crops located at lower altitude, nearer to the city

BBCH scale (Meier et al 2009):

50: Inflorescence buds in leaf axils completely closed.
51: Inflorescence buds starting to swell on stem
52: Inflorescence buds open.
54: Flower clusters growing.
57: The corolla, green-coloured, is longer than the calyx.
61: Beginning of flowering: 10% of flowers open.
65: Full flowering: at least 50% of flowers open.
67: First petals falling.
68: Majority of petals fallen or faded.
69: End of flowering, fruit set, non-fertilized ovaries fallen

Oteros et al 2013. *Agriculture,Ecosystems and Environment,* 179:62– 68

The major variables governing local olive reproductive phenology

Olive in Córdoba

Topographical variables

(1) Altitude (m);
(2) maximum slope inclination (%);
(3) maximum slope orientation (%):
   a. from South to North,
   b. from East to West.

Altitude and maximum slope orientation were the main factors responsible for differences in phenophase timing

Weather-related variables

(1) Average maximum and minimum temperature;
(2) cumulative rainfall;
(3) Chilling Units (CU)
(4) Growing Degree Days (GDD),
(5) potential Evapotranspiration for the olive crop (Etc)
(6) cumulated rainfall minus ETc (Rf-ETc);
(7) net Radiation (Rn).

The variables most influencing phenological development were heat-related parameters.

Water availability at the beginning of the year also had a marked influence on all phenophases

Oteros et al 2013. *Agriculture,Ecosystems and Environment,* 179:62– 68

COST Action ES0603: EUPOL

Assessment of production, release, distribution and health impact of allergenic pollen in Europe

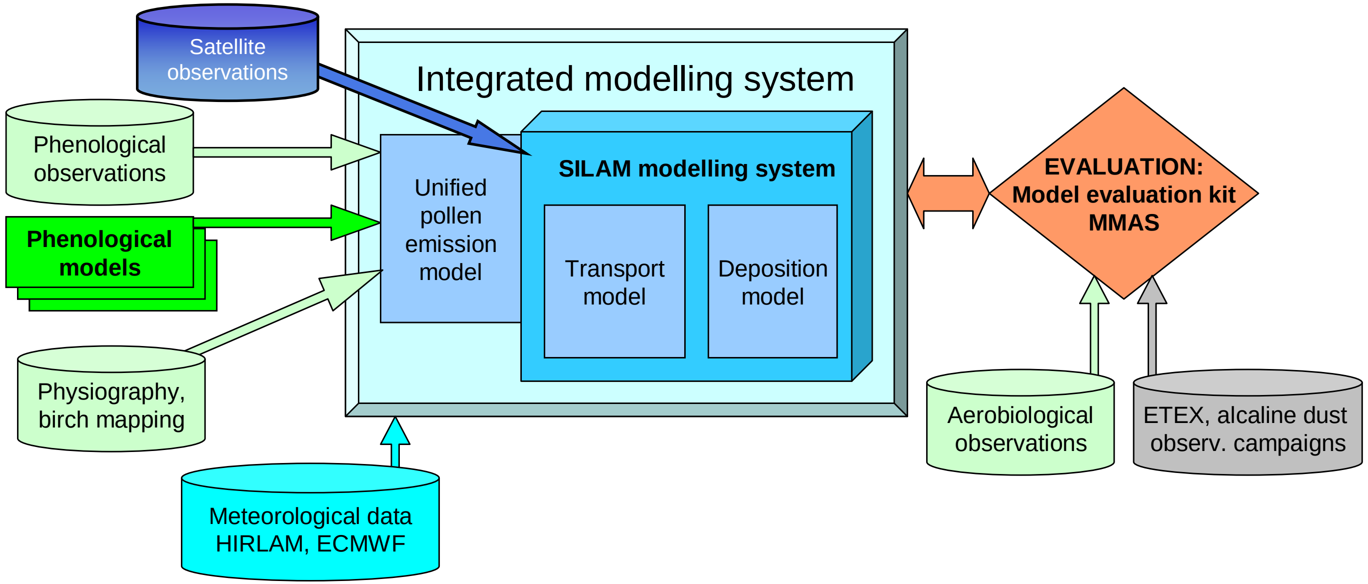
http://www.unifi.it/COSTEupol/index.html

Main objective:

to set up a multi-disciplinary forum for critical review of existing information on allergenic pollen in Europe and its representation in assessment and forecasting systems.

Secondary objectives:

- identification of the critical gaps in the current knowledge;
- better co-ordination of on-going research;
- development of a comprehensive strategy and specific action plan for improving the scientific knowledge and converting the findings into integrated assessment systems;
- strengthening the dialogue with end users.

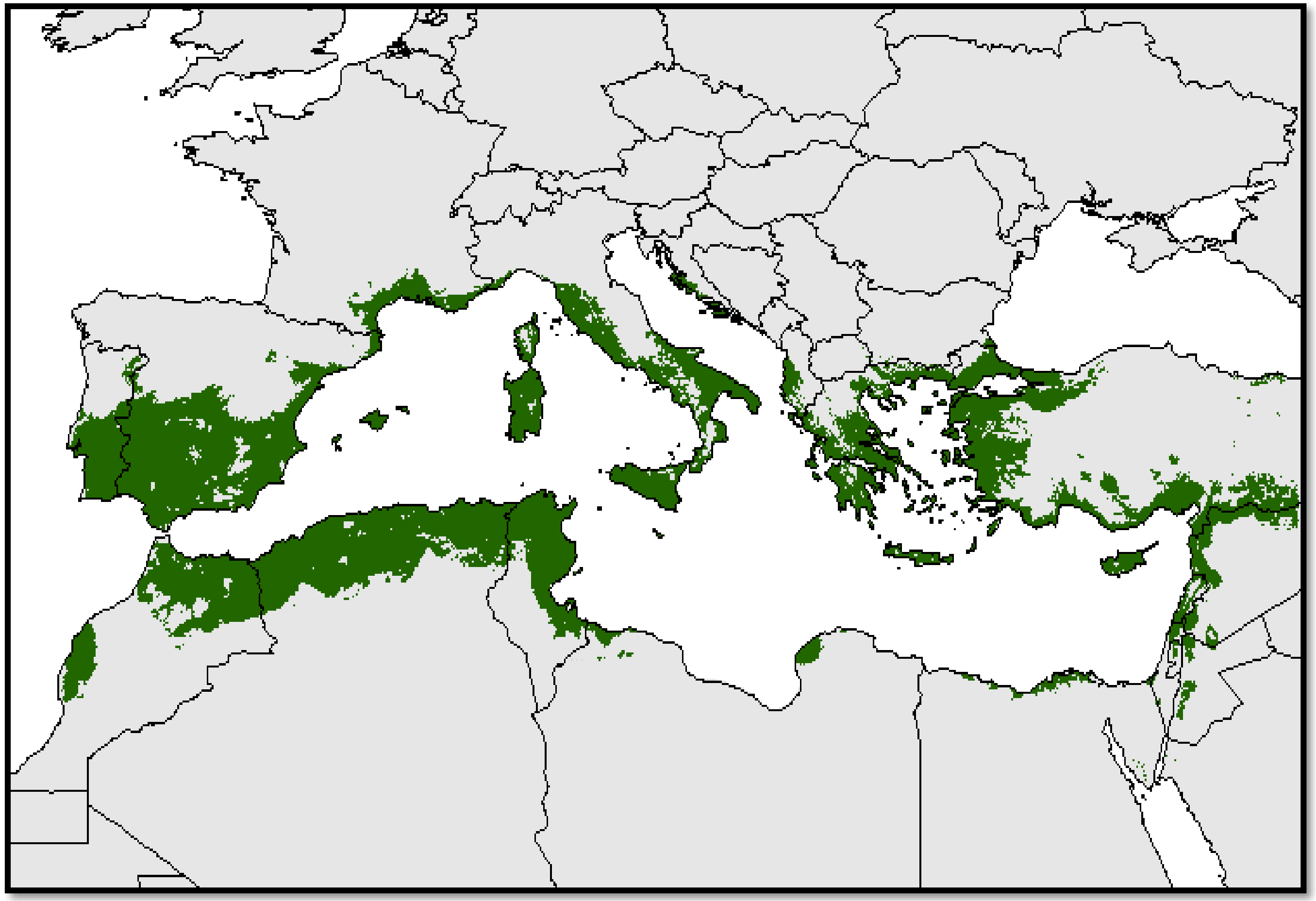


Pollen Sources

Inventories of airborne pollen sources

Botton-Up inventories for pollen-producing species

Olive groves in the Mediterranean Basin



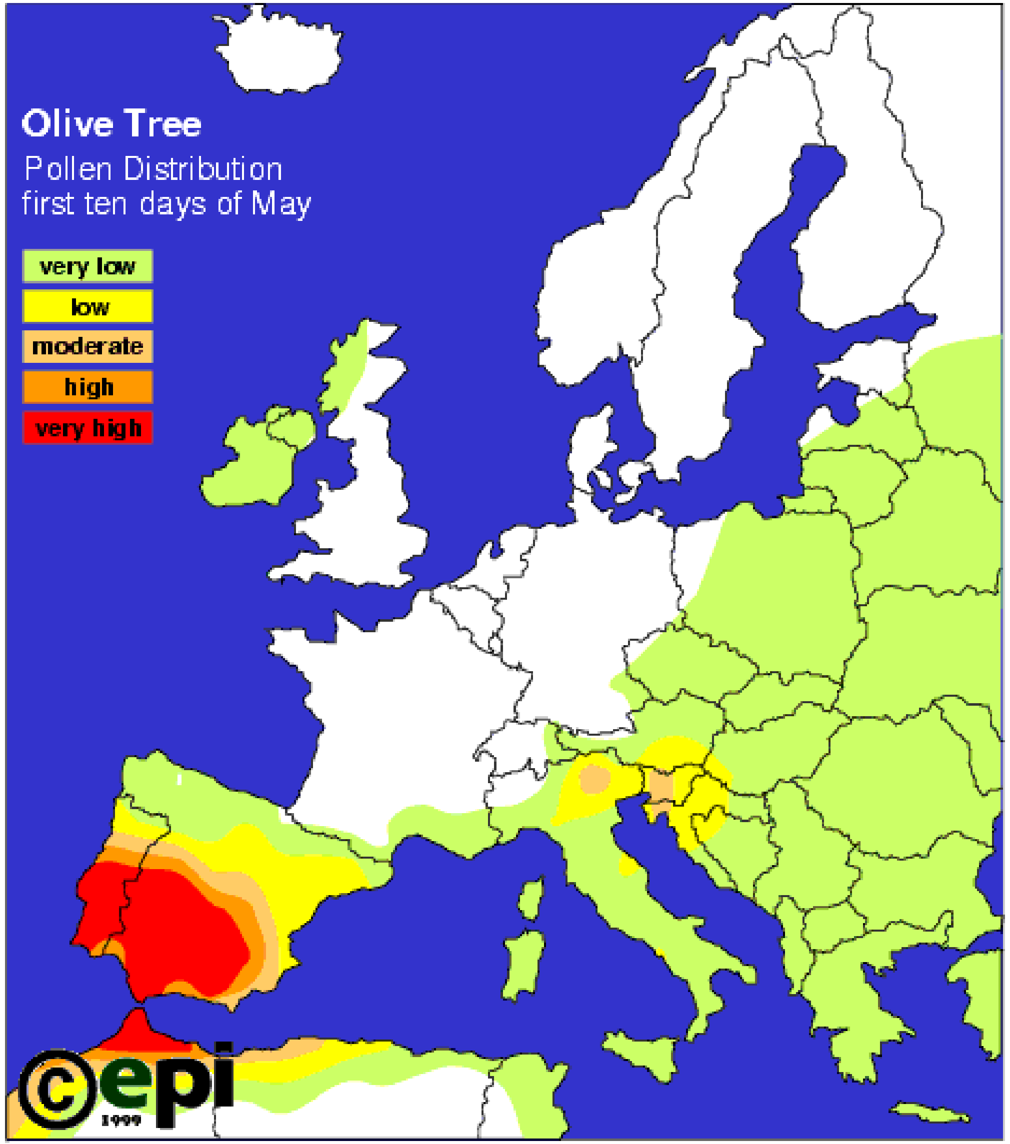
https://es.wikipedia.org/wiki/Olea_europaea#cite_note-Oteros_.282014.29-7

Pollen Sources

Inventories of airborne pollen sources

Top-Down inventories for anemophilous species

Airborne Pollen Monitoring Networks,
i.e. European Aeroallergen Network (EAN)

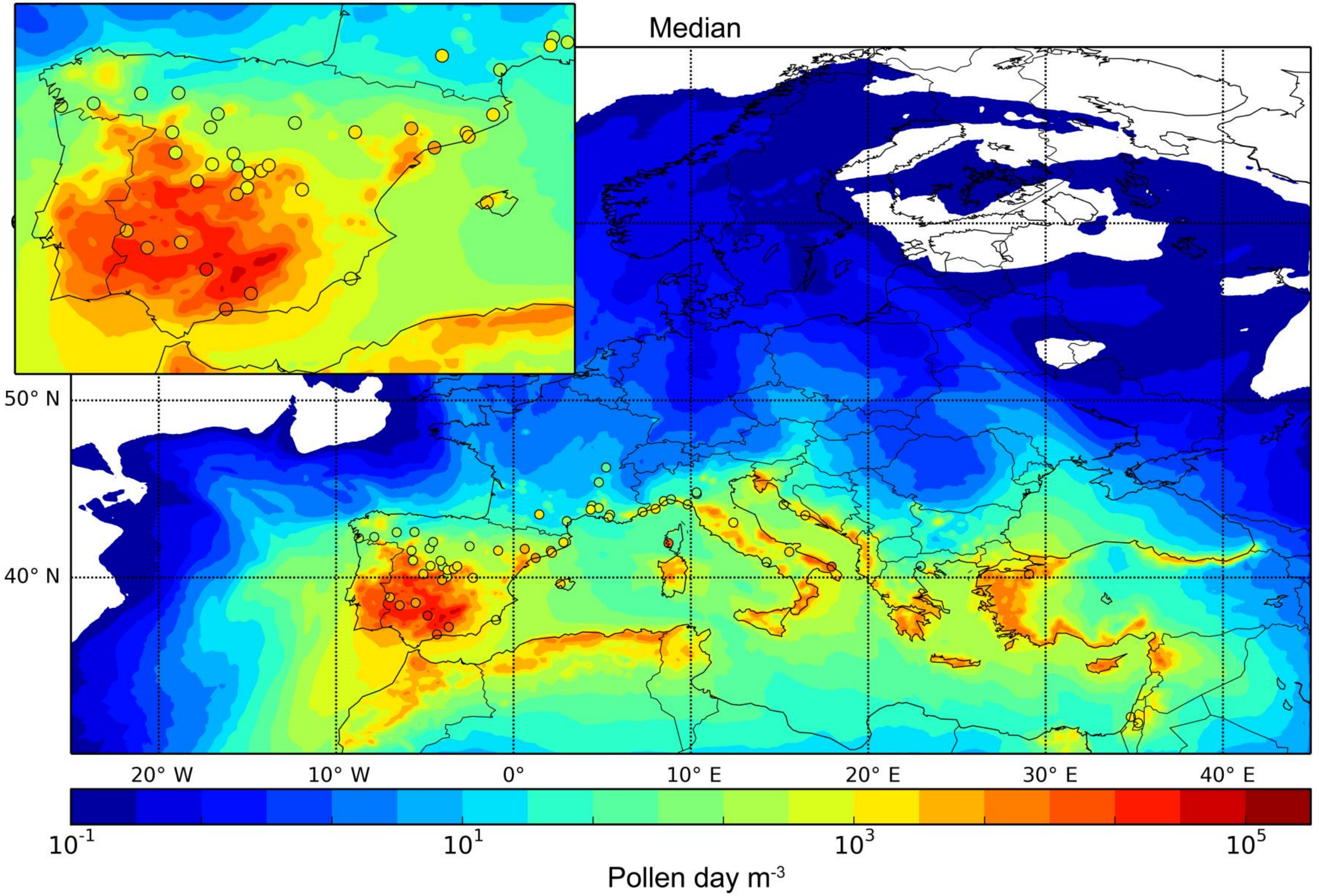


https://ean.polleninfo.eu/Ean/

Pollen Sources

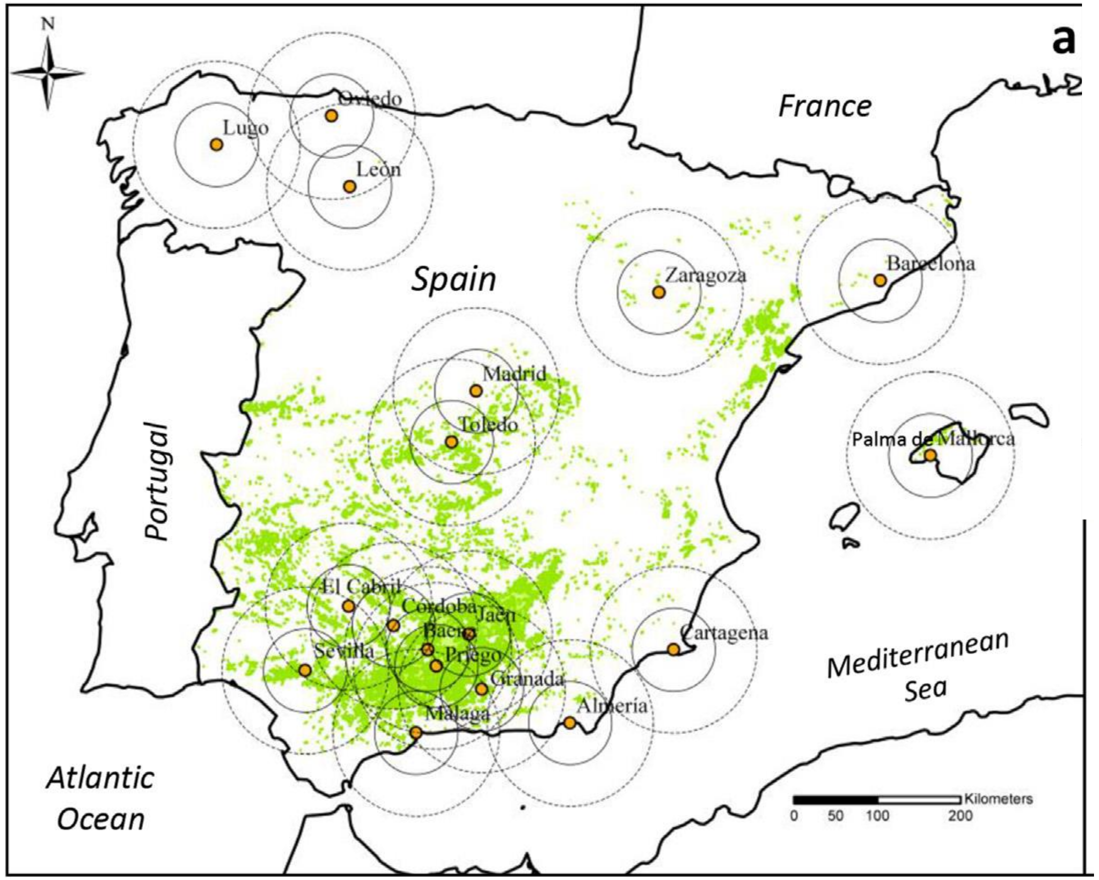
Inventories of airborne pollen sources

Top-Down and Bottom-Up information



Sofiev et al. 2017. *Atmos. Chem. Phys.*, 17:12341–12360

Flowering Intensity *vs.* Pollen Sources



Concentric Ring Method with different index: Influence Index, and Specific Influence Index.
Pollen sampling points location and olive groves surface, smooth circles show buffers of 50 km radius around each sampling point and dashed circle shows buffers of 100 km radius, as reference distances

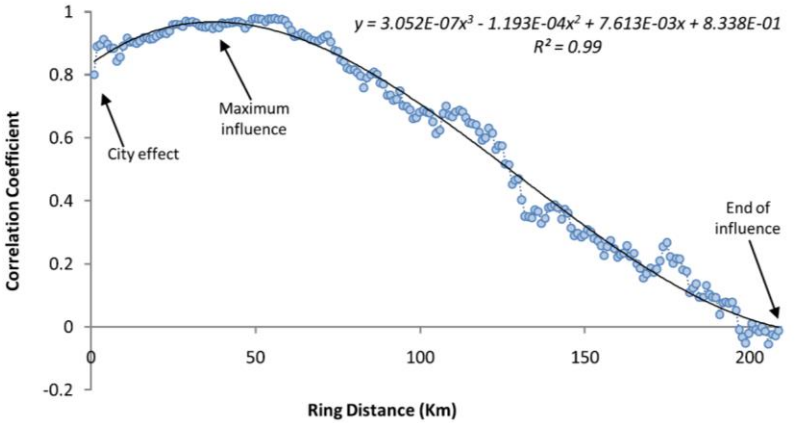
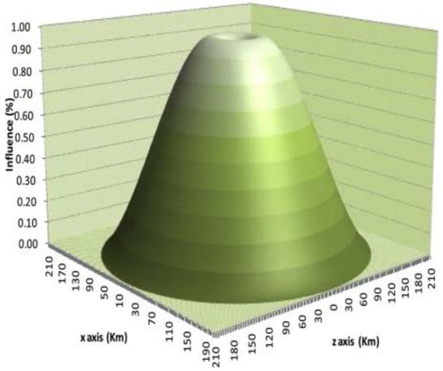
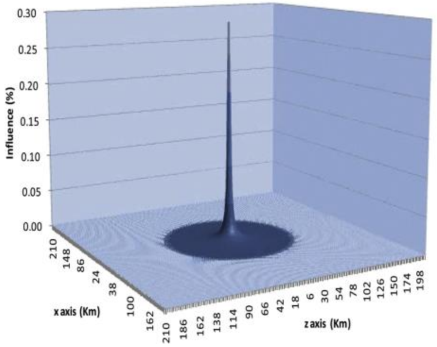


Fig. 2. Polynomial relationship of the correlation coefficient and Pollen Index and Actual Emission Surface on each ring and the ring distance to the sampling point.



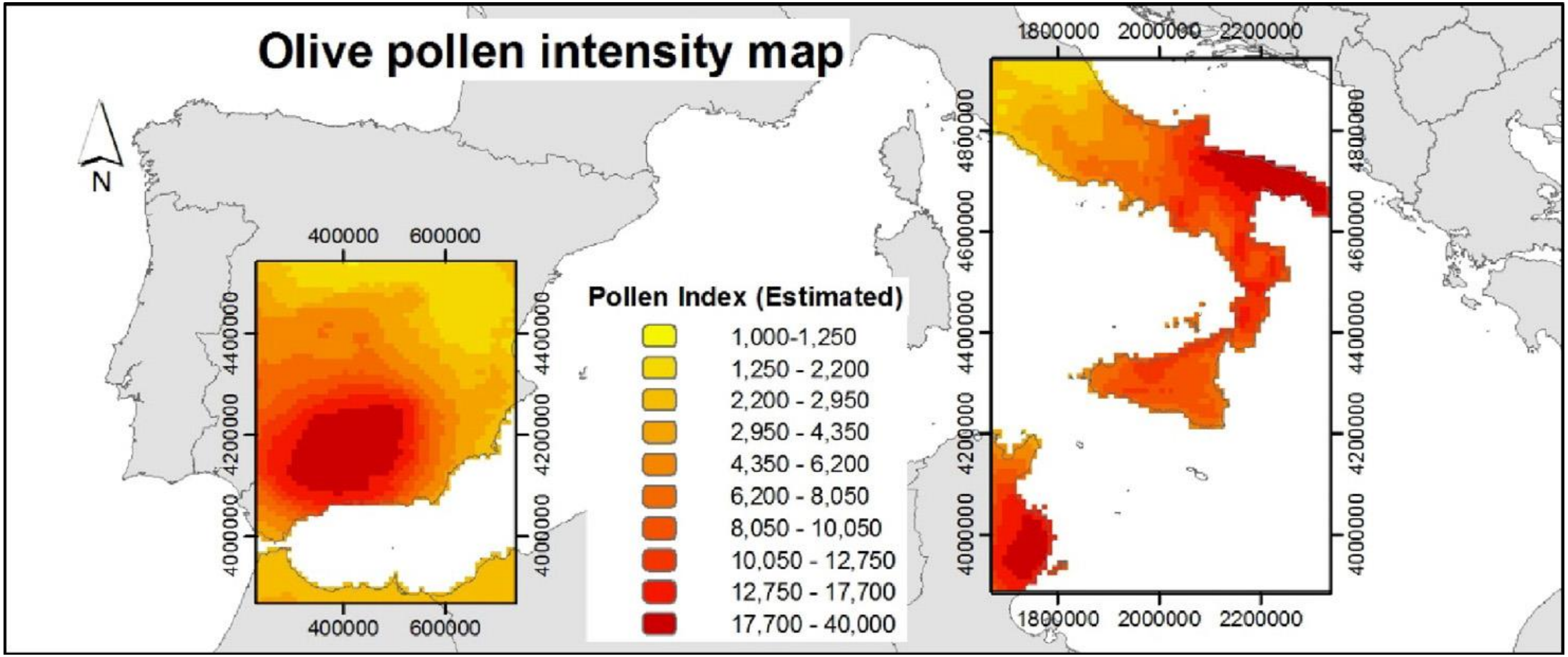
3D-model of influence that has the emission surface of each ring on Pollen Index of sampling point (in center), under theoretical conditions of continuous emission surface.



3D-model of influence that has each Km2 of emission surface on Pollen Index of sampling point (in center), under a theoretical conditions of continuous emission surface

Oteros et al 2015. *Journal of Environmental Management* 155:212-218

Flowering Intensity *vs.* Pollen Sources

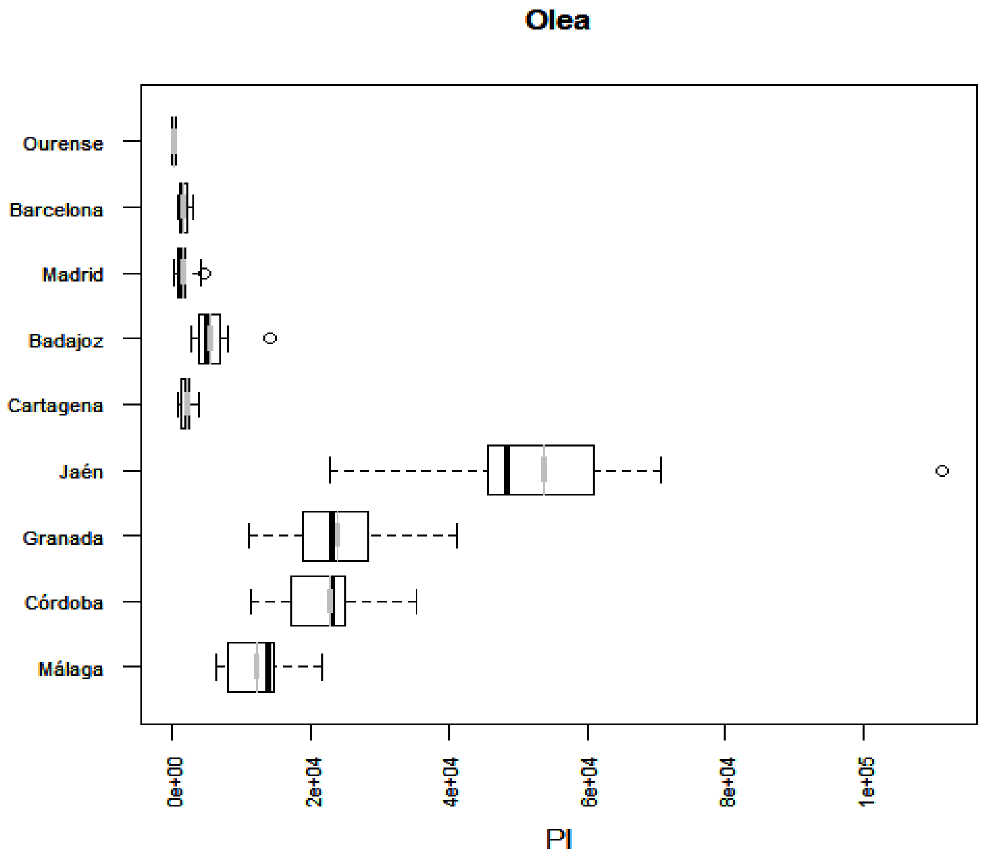


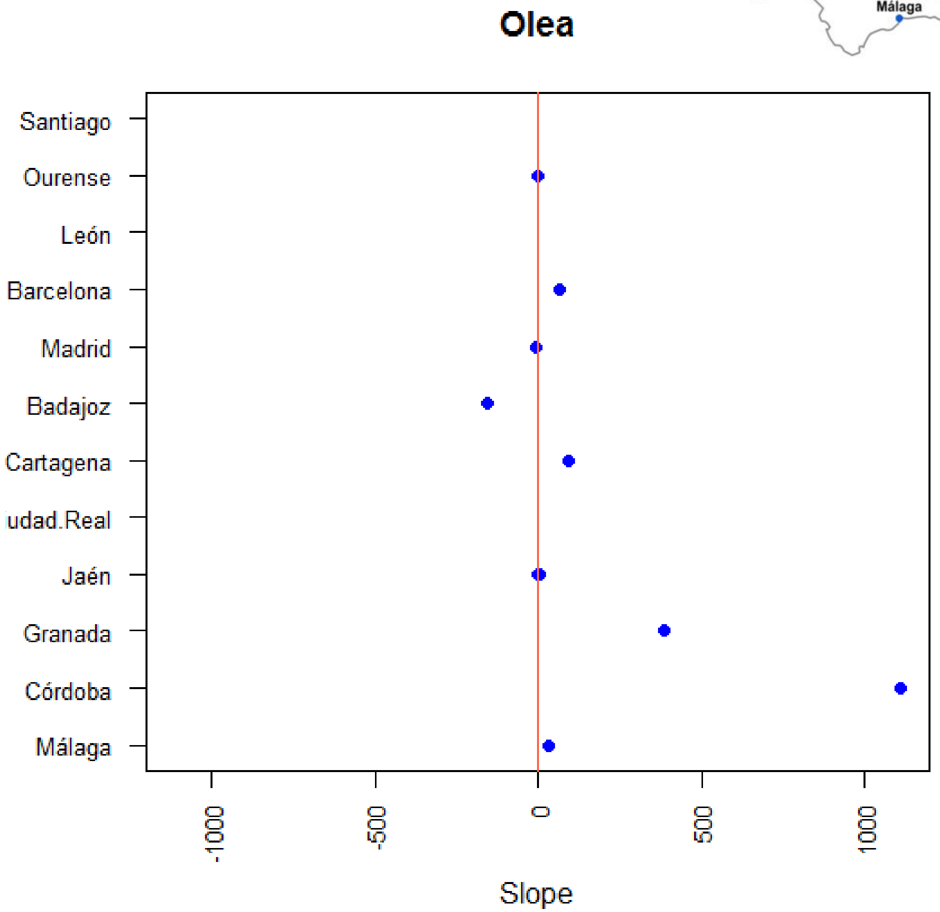
Concentric Ring Method .
Marked differences on dispersal patterns associated to the altitudinal gradient. Areas located at an altitude above 300 m a.s.l. receive greater amounts of olive pollen from shorter-distance pollen sources (maximum influence, 27 km) with respect to areas lower than 300 m a.s.l. (maximum influence, 59 km).

Rojo et al 2016. *Science of the Total Environment* 551–552:73–82

Airborne Pollen Trends in the Iberian Peninsula

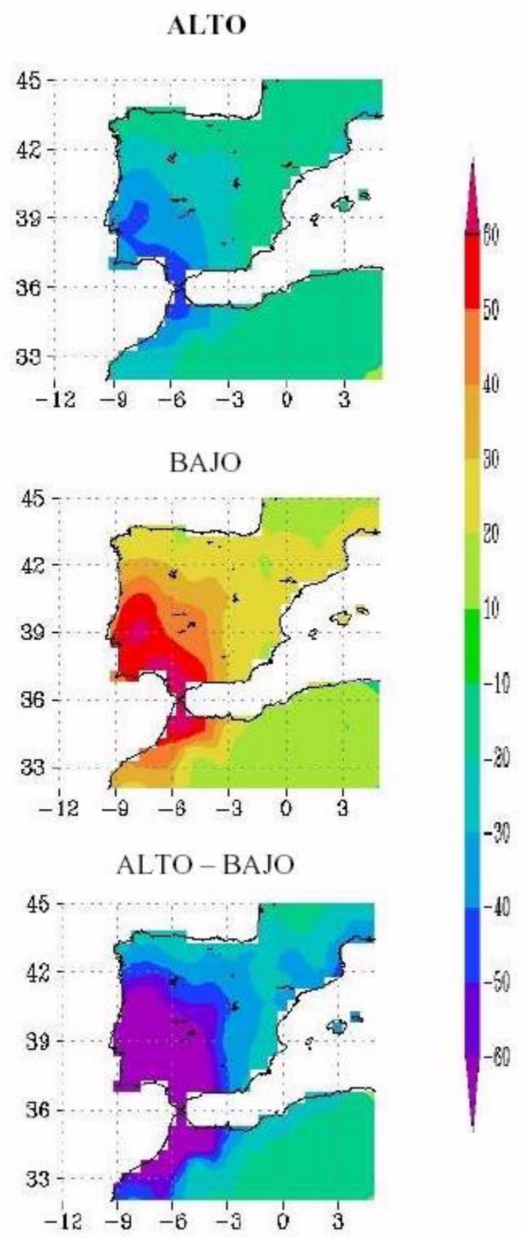
Flowering Intensity

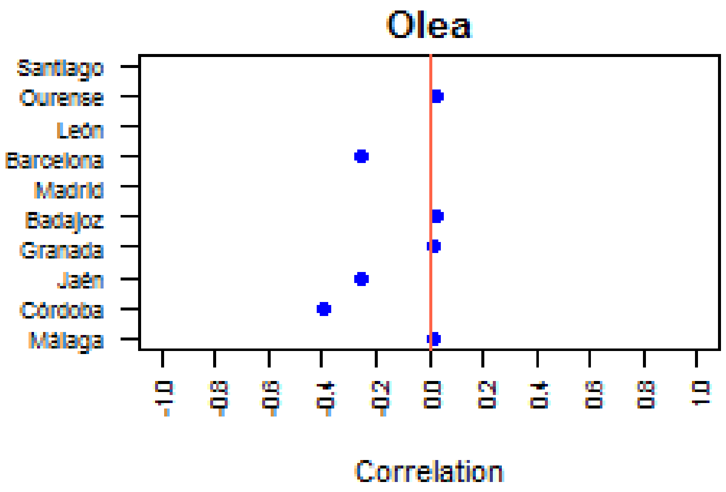


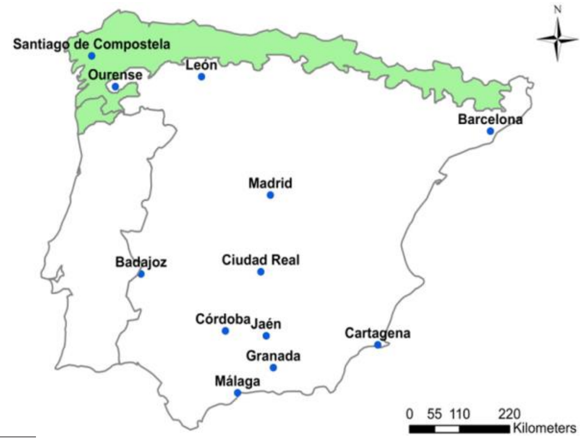


Galán et al 2016. *Science Total Environment*, 500: 53-59

Correlation between Airborne Pollen Index and Winter NAO Index (December –February)







	Olea
Málaga	0.018
Córdoba	−0389**
Jaén	−0.258
Granada	0.019
Cartagena	−0.389
Badajoz	0.026
Madrid	0.017
Barcelona	−0.254
León	
Ourense	0.031
Santiago	

*** Significant ($p \leq 0.001$).
** Significant ($p \leq 0.01$).
* Significant ($p \leq 0.05$).

This study confirms that changes in rainfall in the Mediterranean region, attributed to climate change, have an important impact on the phenology of plants

Galán et al 2016. *Science Total Environment*, 500: 53-59

Olive Crop Forecasting using Pollen-based Models

Fig. 3 Regression coefficients of the important variables in local models (**a**) and national models (**b**). *PI* pollen index; *Rf-Etc.(Oct–Apr)* cumulated rainfall from 1 October of the preceding ($n-1$) year to 30 April minus the evapotranspiration for the olive crop over the same period; *Tmn(Jan)* mean January temperature; *Tmax(Jul)* mean daily maximum July temperature; *Tmn(Sep)* mean September temperature; *Rf(Jan–Jun)* cumulated rainfall from 1 January to 30 June; *Tmax(2nd_Jul)* mean daily maximum temperature for the second 10 days of July; *Tmn(Oct)* mean October temperature; *Rf(Mar)* cumulated rainfall from 1 to 31 March; *Tmax(1st_May)* mean daily maximum temperature in the first 10 days of May; *Tmin(1st_Mar)* mean daily minimum temperature in the first 10 days of March; *Tmax(3rd_May)* mean daily maximum temperature in the last 10 days of May; *Tmax(Aug)* mean daily August maximum temperature; *Tmin(3rd_Apr)* mean daily minimum temperature in the last 10 days of April

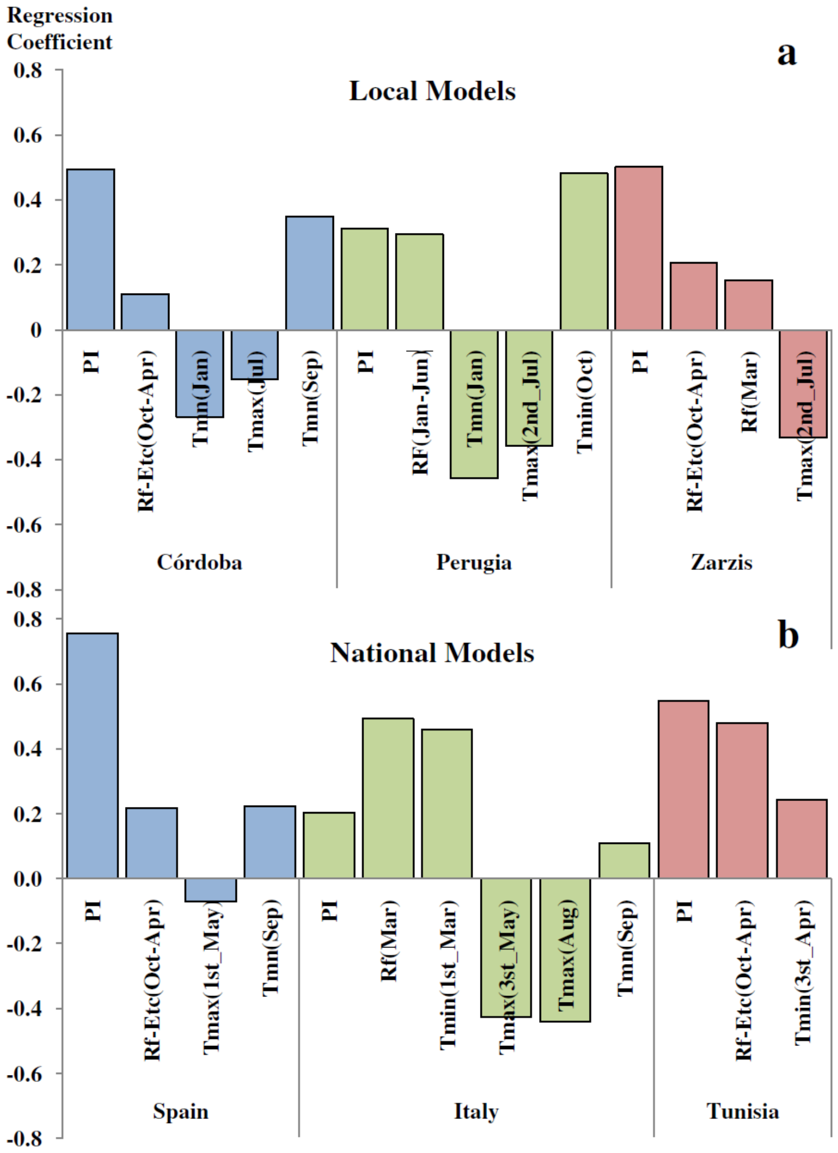
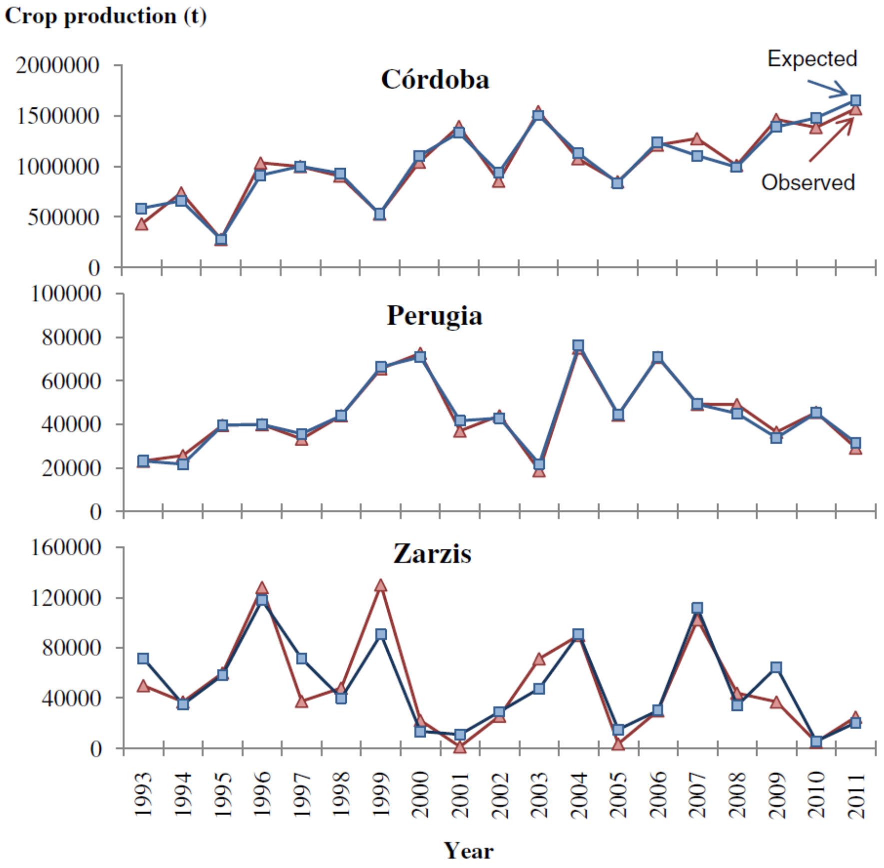


Fig. 4 Yearly crop production as observed and as expected according to the indicated local models; *t* metric tons. These models were validated using the full cross-validation. As can be seen, these local models can be used effectively for crop forecasting purposes



1st forecasting just after flowering end
2nd forecasting during autumn

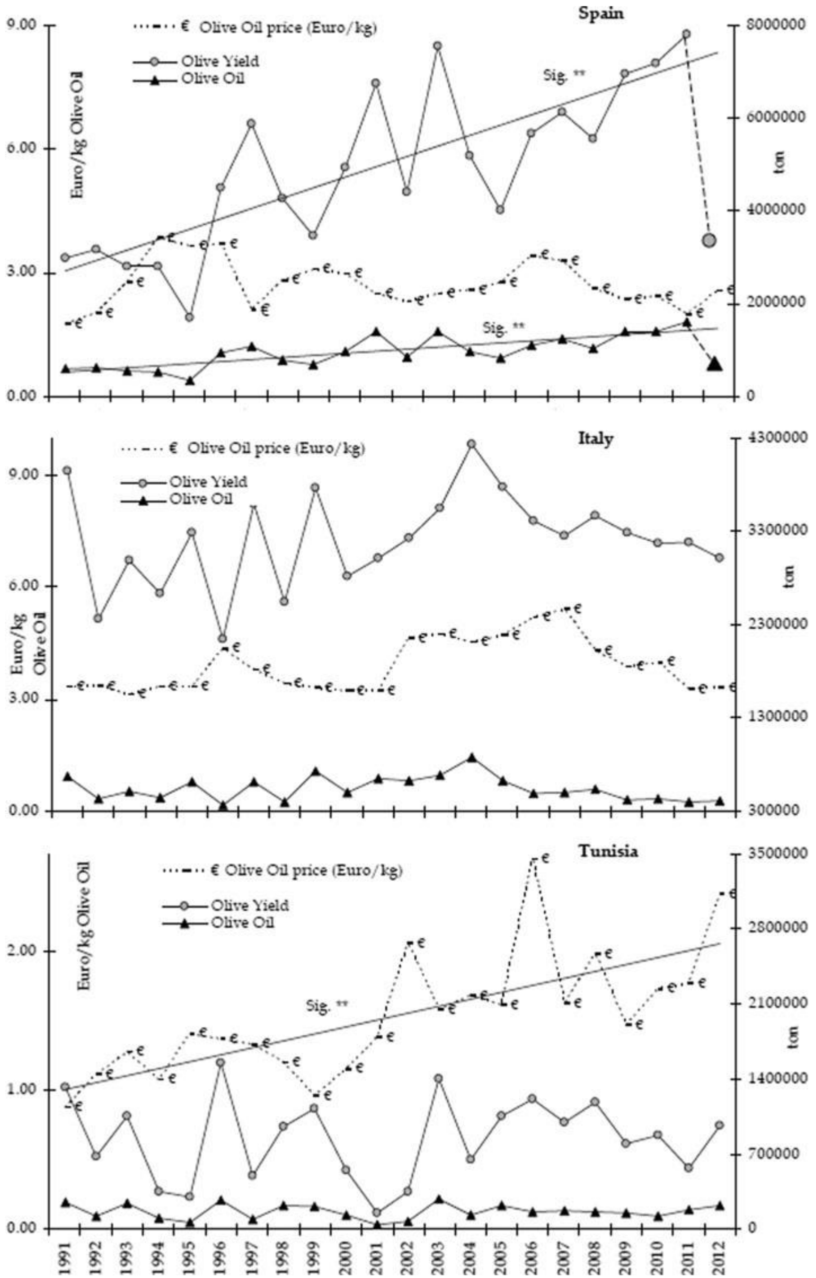
Oteros et al 2014. *Agron. Sustain. Dev.* 34:685–694

Olive Crop Forecasting using Pollen-based Models

Clear significant increasing trends for both the fruit and olive oil production. Not clear trend for oil price, in a range between **1.8 to 3.8 euro kg⁻¹**

Not clear trends for fruit, olive oil production and neither the price. Lower production than in Spain but higher price, in a range between **3 to 5 euro kg⁻¹**

Not clear trends for fruit and olive oil production, with high annual oscillations. **Clear significant increasing trends for price**, with two sub-series: a) 1991-2001, in a range between **0.9 to 1.4 euro kg⁻¹**; b) last decade, in a range between **1.5 to 2.5 euro kg⁻¹**

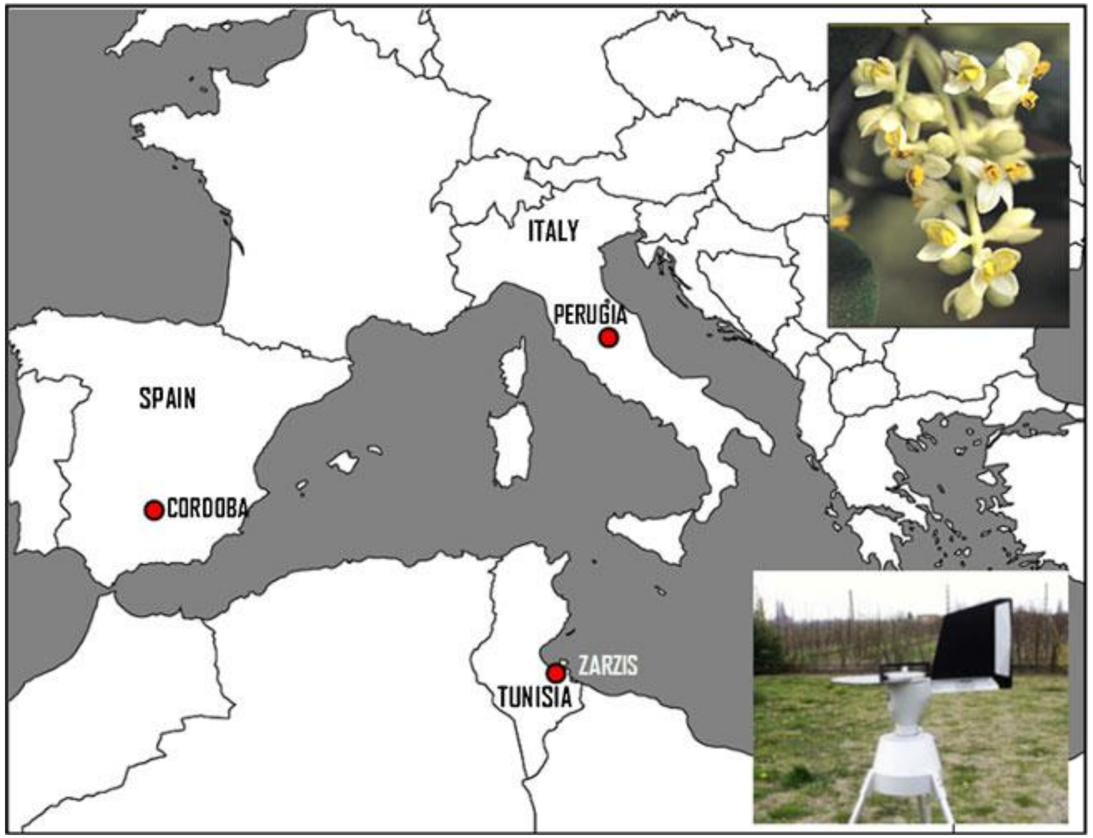


Difficulty to define clear relationships with oil price for optimizing the marketing strategies, due to the olive sector European policy and to the complex international olive oil market situation

Temporal trends for olive yield (ton), olive oil production (ton) and olive oil price (euro kg−1). Trend significance (Sig.): ∗∗, a = 0.01 (highly significant); ∗, a = 0.05 (significant); +, a = 0.1 (nearly significant).

Orlandi et al 2017. *Experimental Agriculture*, 53: 71-83

Flowering Timing Modelling



Process-based models during pre-flowering

- ✓ Sequential flow among phases
- ✓ Each phase has input and output
- ✓ To start a phase the previous phases must be accomplished
- ✓ Bimodal pattern in its yearly vegetative cycle




From winter to spring

From late spring to winter

Winter

Early spring

Spring

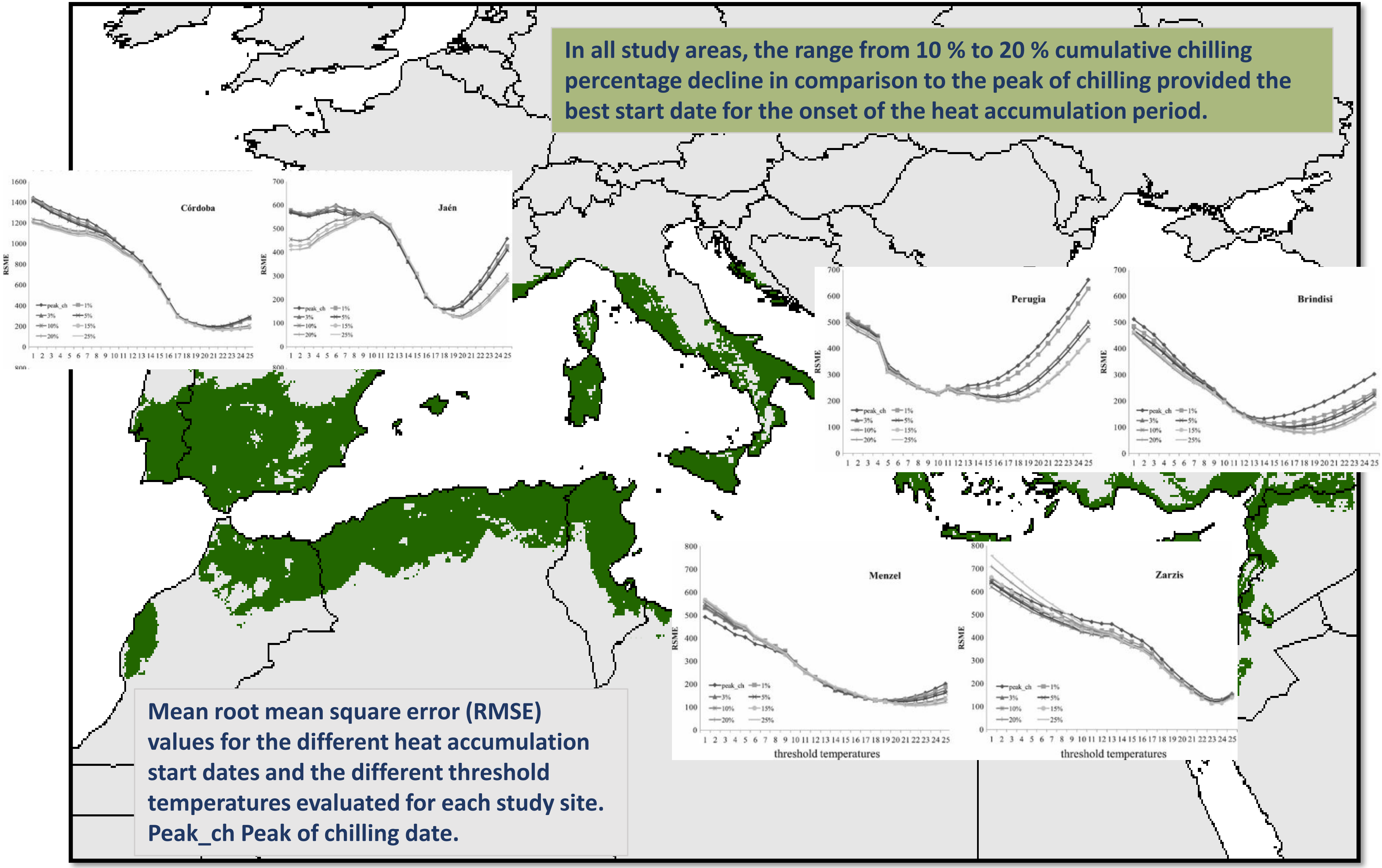
Bud induction	Bud latency	Chilling units	Forcing units	Flowering

Thermoperiodicity and vernalization

Morin et al. 2007 *Ecology*. 88:2280-91

Chilling and Forcing units of olive in the Mediterranean Basin

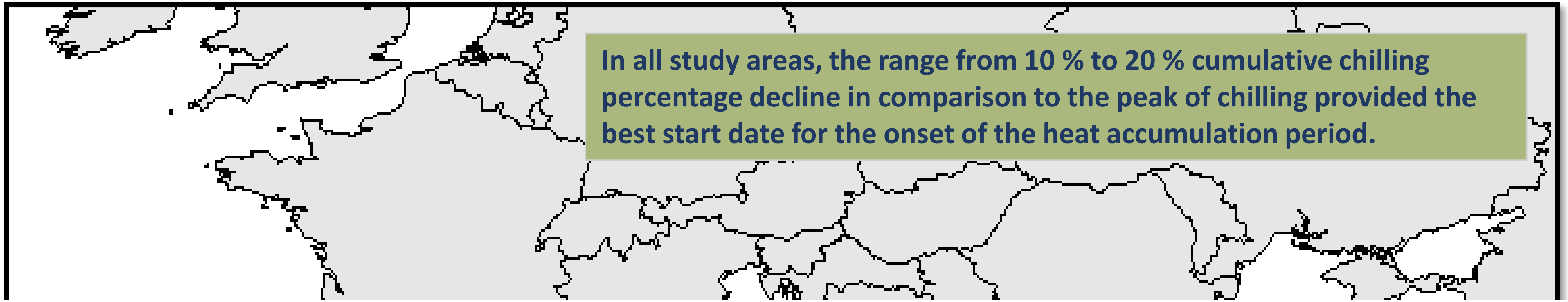
In all study areas, the range from 10 % to 20 % cumulative chilling percentage decline in comparison to the peak of chilling provided the best start date for the onset of the heat accumulation period.



Mean root mean square error (RMSE) values for the different heat accumulation start dates and the different threshold temperatures evaluated for each study site. Peak_ch Peak of chilling date.

Aguilera et al. *Int J Biometeorol* (2014) 58:867–876

Chilling and Forcing units of olive in the Mediterranean Basin



In all study areas, the range from 10 % to 20 % cumulative chilling percentage decline in comparison to the peak of chilling provided the best start date for the onset of the heat accumulation period.

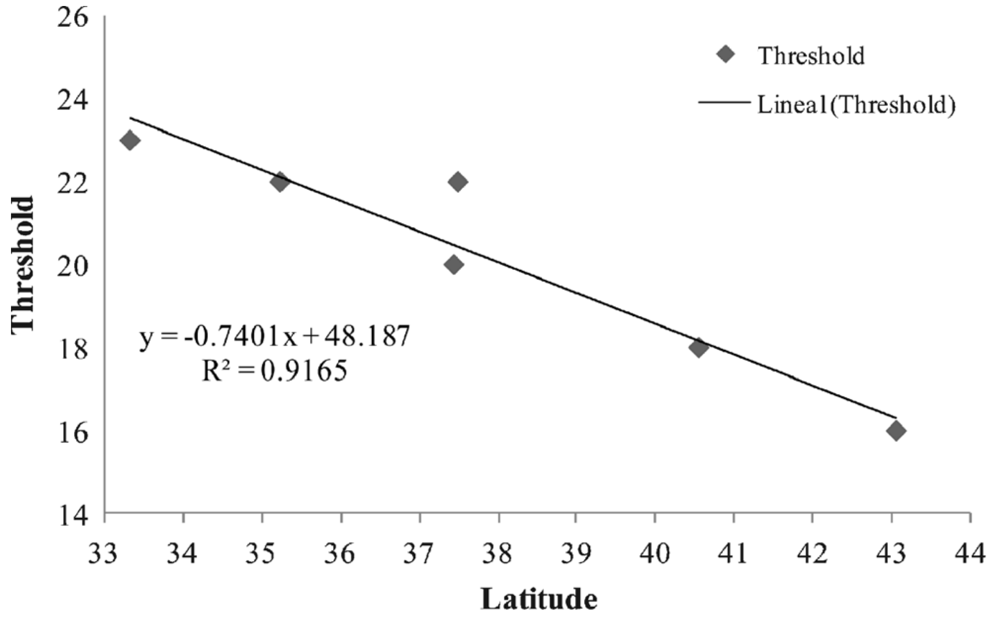
Int J Biometeorol (2014) 58:867–876 871

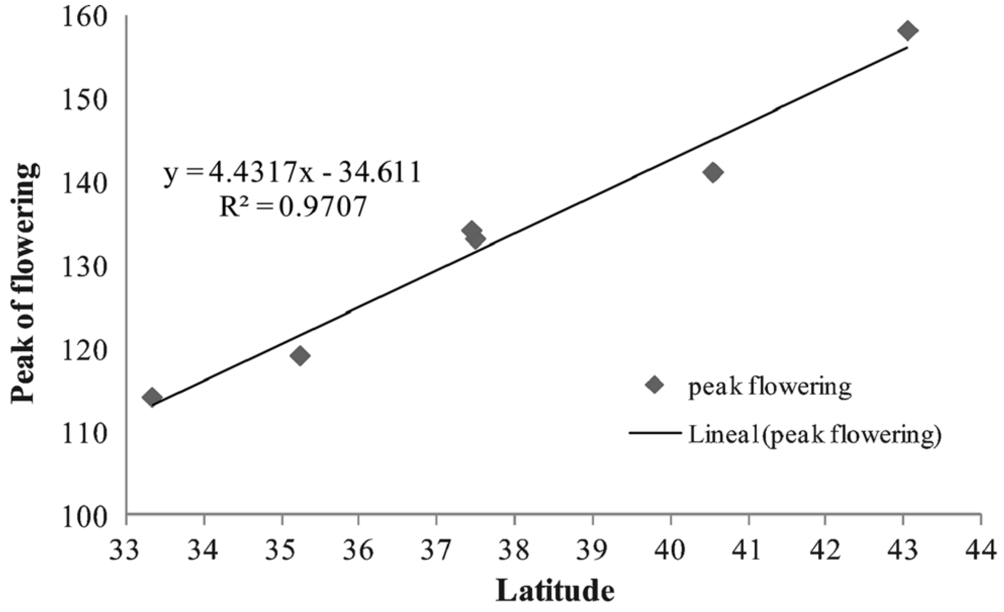
Table 2 Average values of the main characteristics of the heat accumulation period in each study area. *Peak_ch* Peak of chilling date, *Start_ht* heat accumulation start date, *Peak_fl* peak of flowering date, *GDD* growing degree days amounts

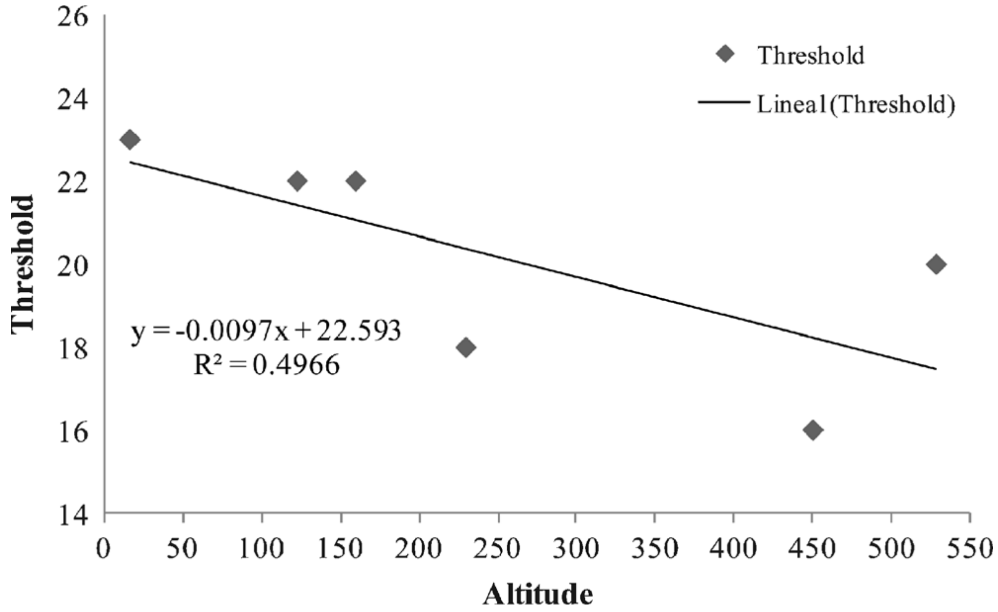
Study area	Peak_ch	Start_ht	Peak_fl	Threshold	GDD	Peak_ch/ Start_ht	Length heat period	Peak_ch/ Peak_fl
Perugia	18±7	46±10	158±6	16	200±47	28	112	140
Brindisi	20±6	41±8	141±4	18	123±30	21	100	121
Córdoba	11±6	37±8	133±13	22	119±38	26	96	122
Jaén	11±9	39±9	134±7	20	114±28	28	95	123
Menzel	22±7	36±7	119±8	22	81±25	14	83	97
Zarzis	22±6	32±8	114±9	23	83±27	10	82	92

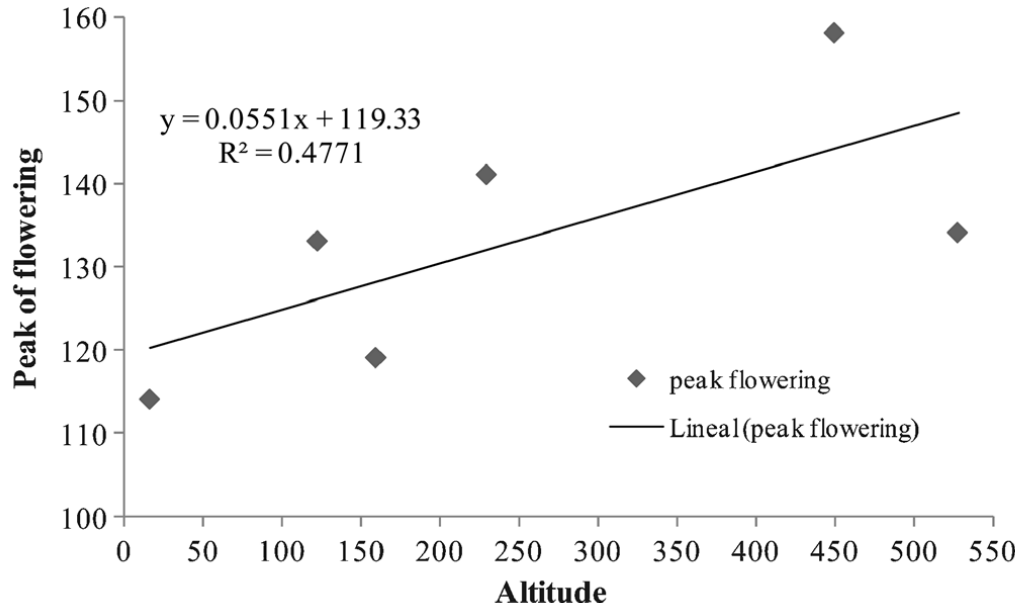
Aguilera et al. *Int J Biometeorol* (2014) 58:867–876

Chilling and Forcing units of olive in the Mediterranean Basin







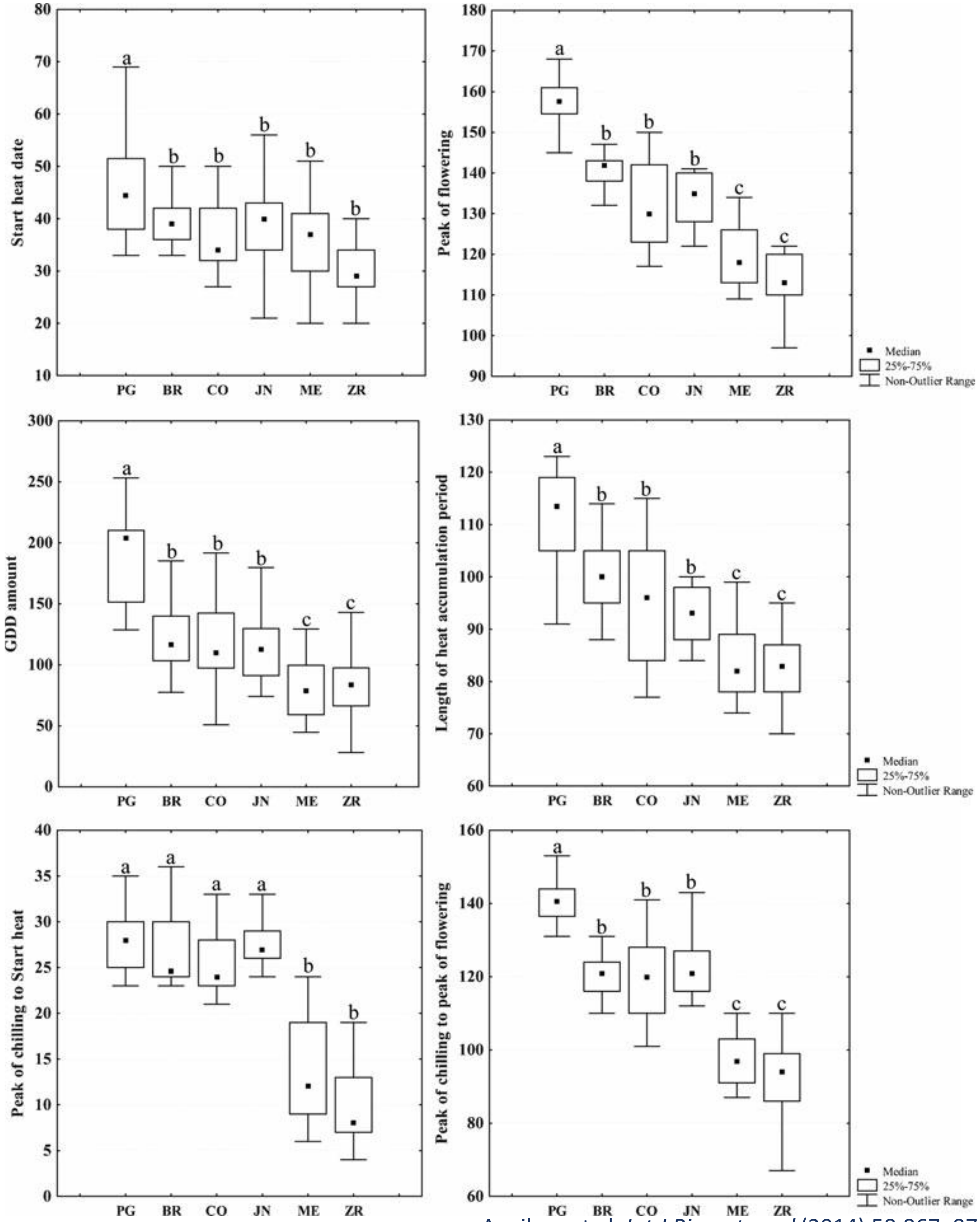


Aguilera et al. *Int J Biometeorol* (2014) 58:867–876

Chilling and Forcing units of olive in the Mediterranean Basin

Northern olive populations have the greatest heat requirements for development of their floral buds and they need a longer period of time than olives in other areas to completely satisfy their biothermic requirements.

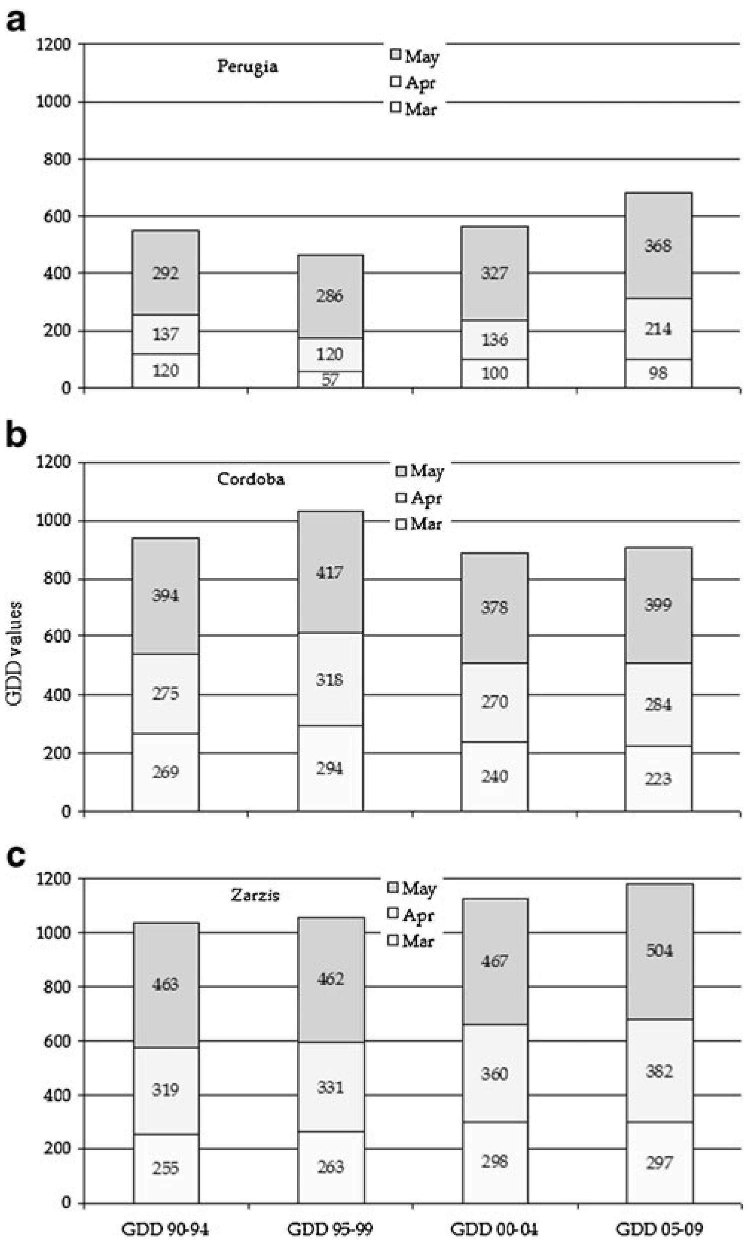
The olive trees located in the warmest winter areas have a faster transition from endogenous to exogenous inhibition once the peak of chilling is met, and they show more rapid floral development.



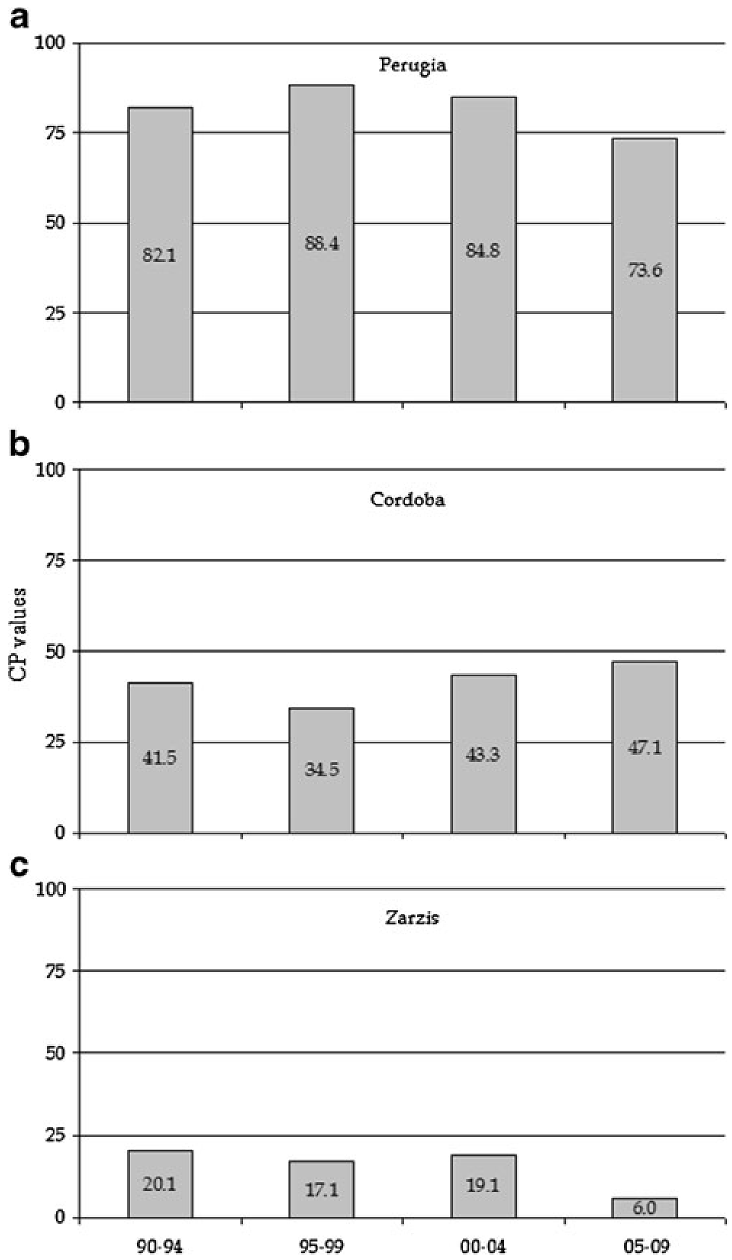
Box-plots of the different parameters studied. PG Perugia, BR Brindisi, CO Córdoba, JN Jaén, ME Menzel, ZR Zarzis. Different letters indicate statistically different values (P≤0.05)

Aguilera et al. *Int J Biometeorol* (2014) 58:867–876

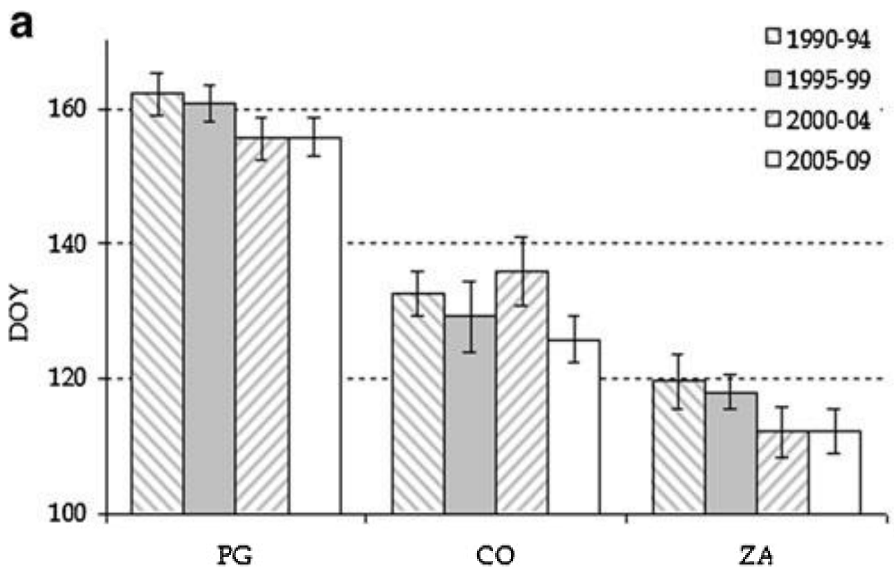
Flowering start during four sub-periods of 5 years



Growing degree days during spring



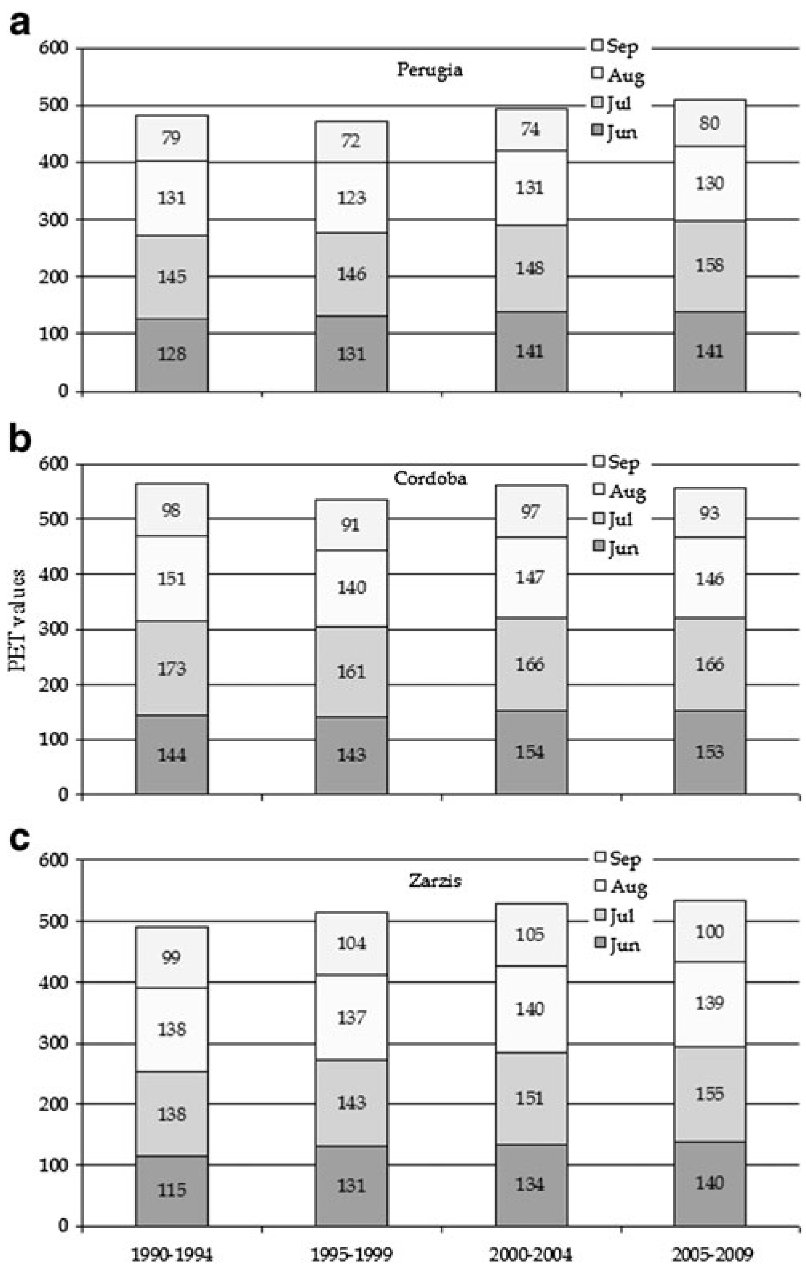
Chilling portions (CP)



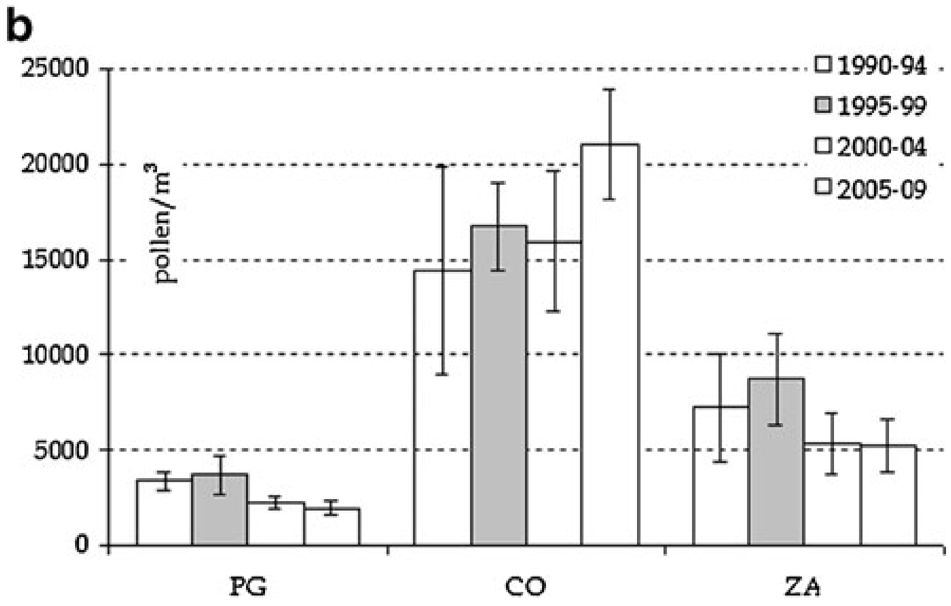
Flowering start

Orlandi et al 2014. *Theor Appl Climatol* 115:207–218

Flowering intensity during four sub-periods of 5 years



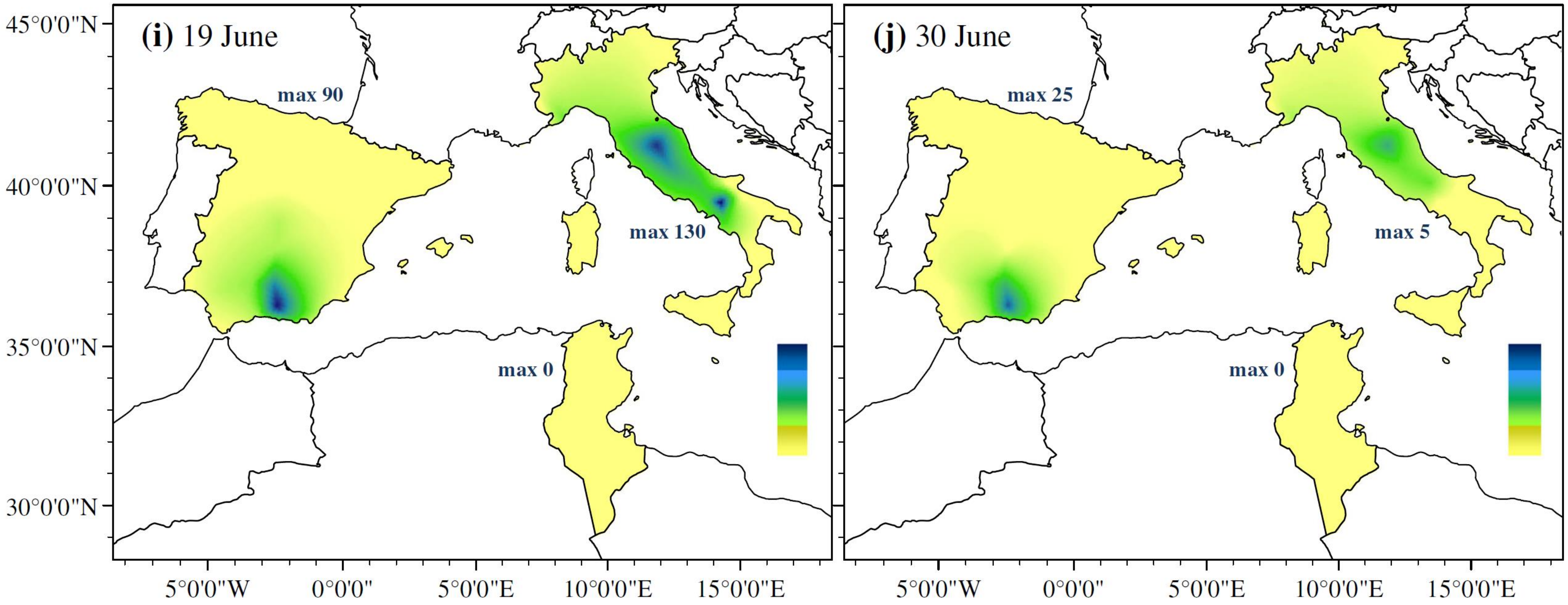
Potential evapotranspiration during summer



Flowering intensity

Orlandi et al 2014. *Theor Appl Climatol* 115:207–218

Spatio-temporal interpretation of olive airborne-pollen maps

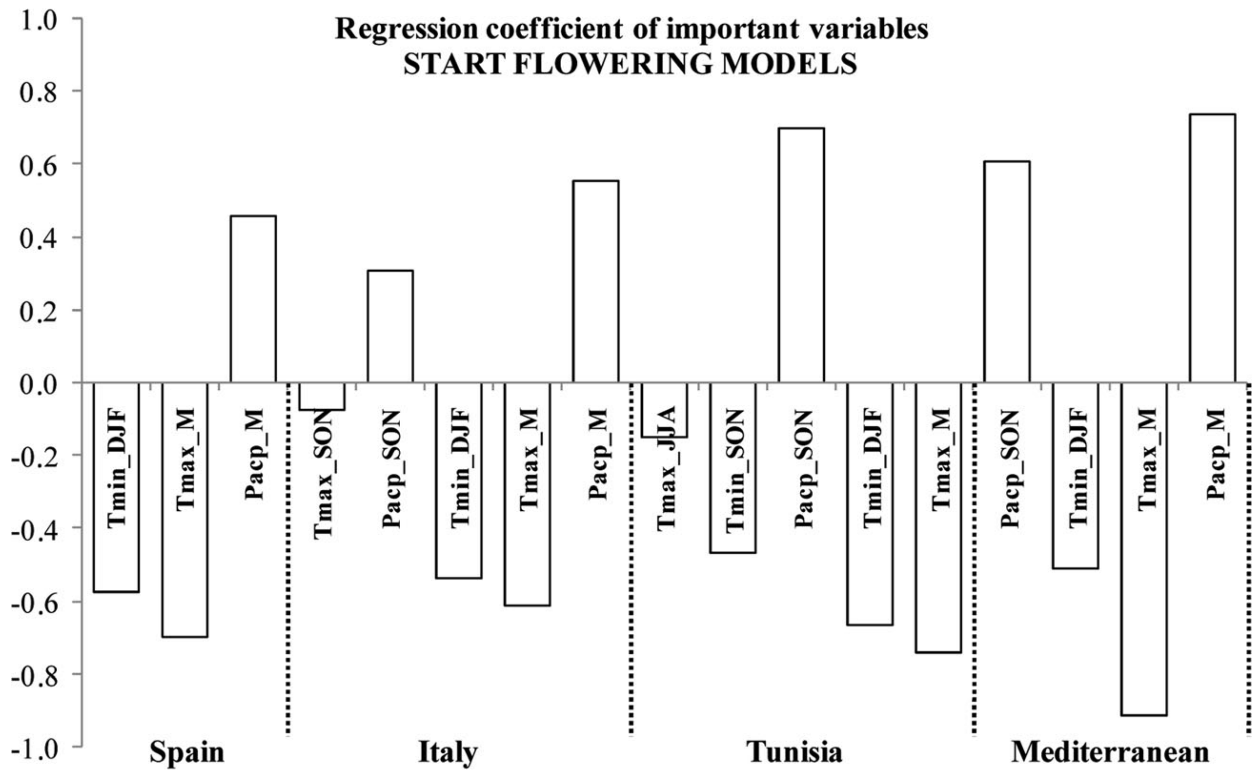


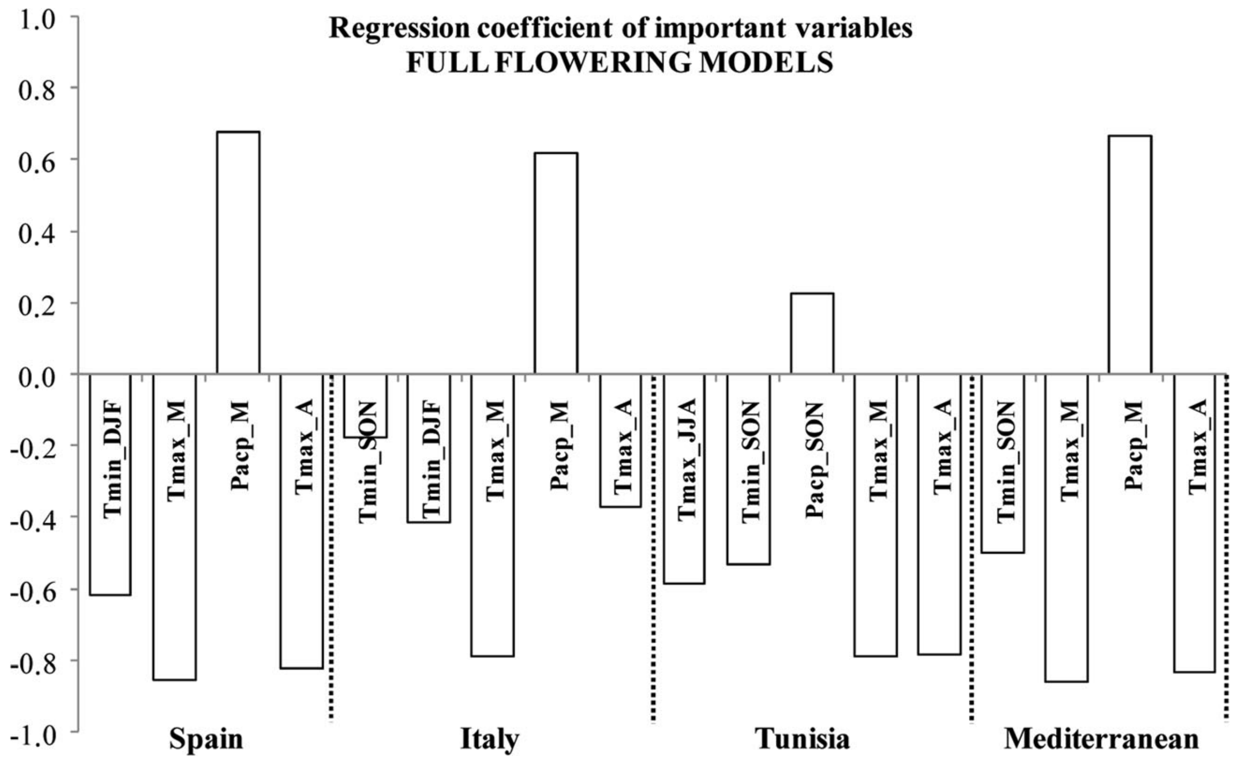
Maps elaborated for different 10-day period through spring and summer

Early flowering in Tunisia coastal zones indicate the onset of the olive pollen season in the occidental Mediterranean region, while the central areas in Italy can indicate the end of the olive pollen release season

Aguilera et al 2015. *Aerobiologia*, 31:421–434

Phenological models to predict the main flowering phases and projections



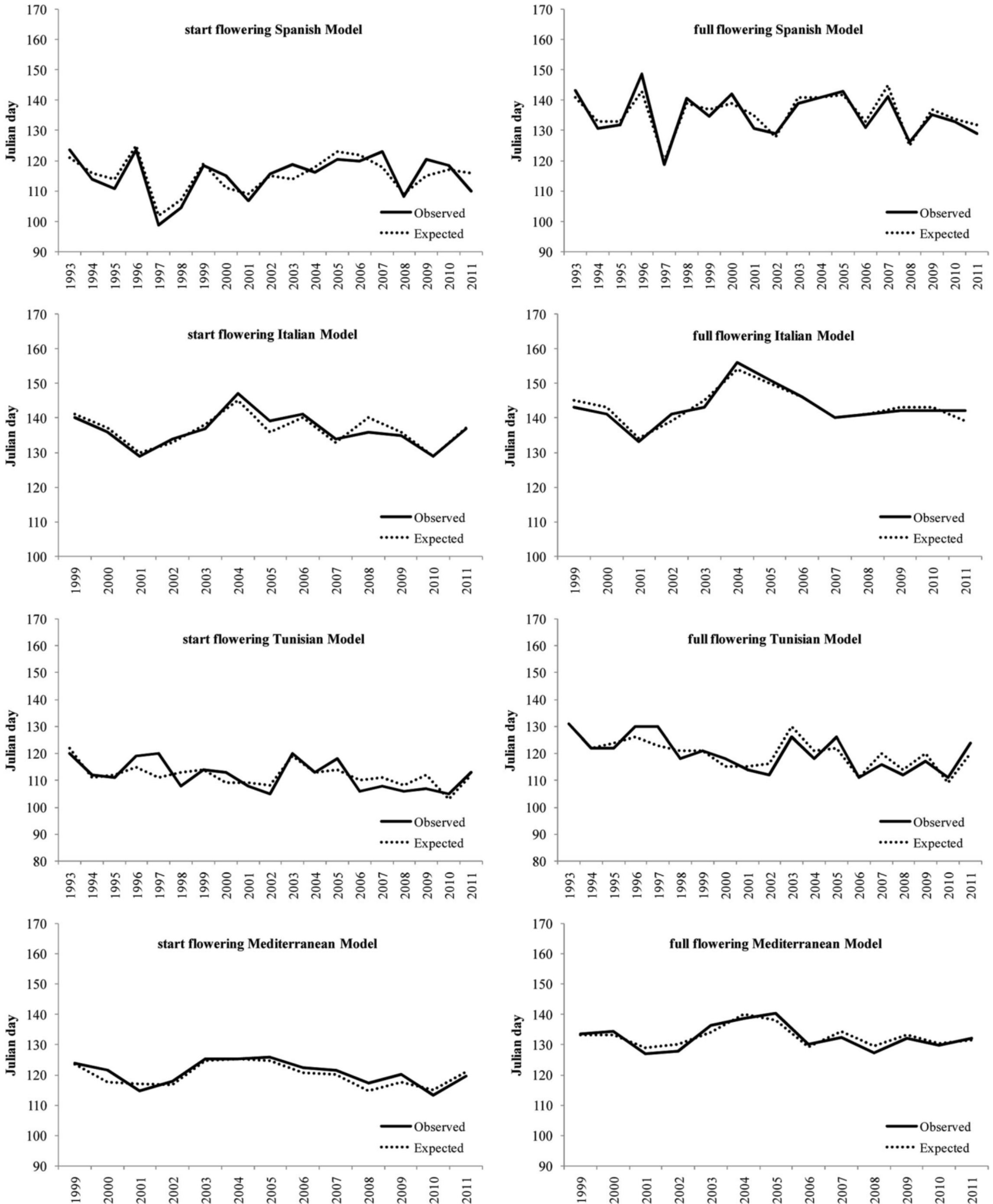


June, July, and August (JJA; summer); September, October, and November (SON; autumn); and December, January, and February (DJF; winter).

Statistical analyses between the flowering dates and meteorological parameters from summer of previous year to late-spring of the flowering year

Aguilera et al 2015. *Int J Biometeorol*

Observed and expected value validation



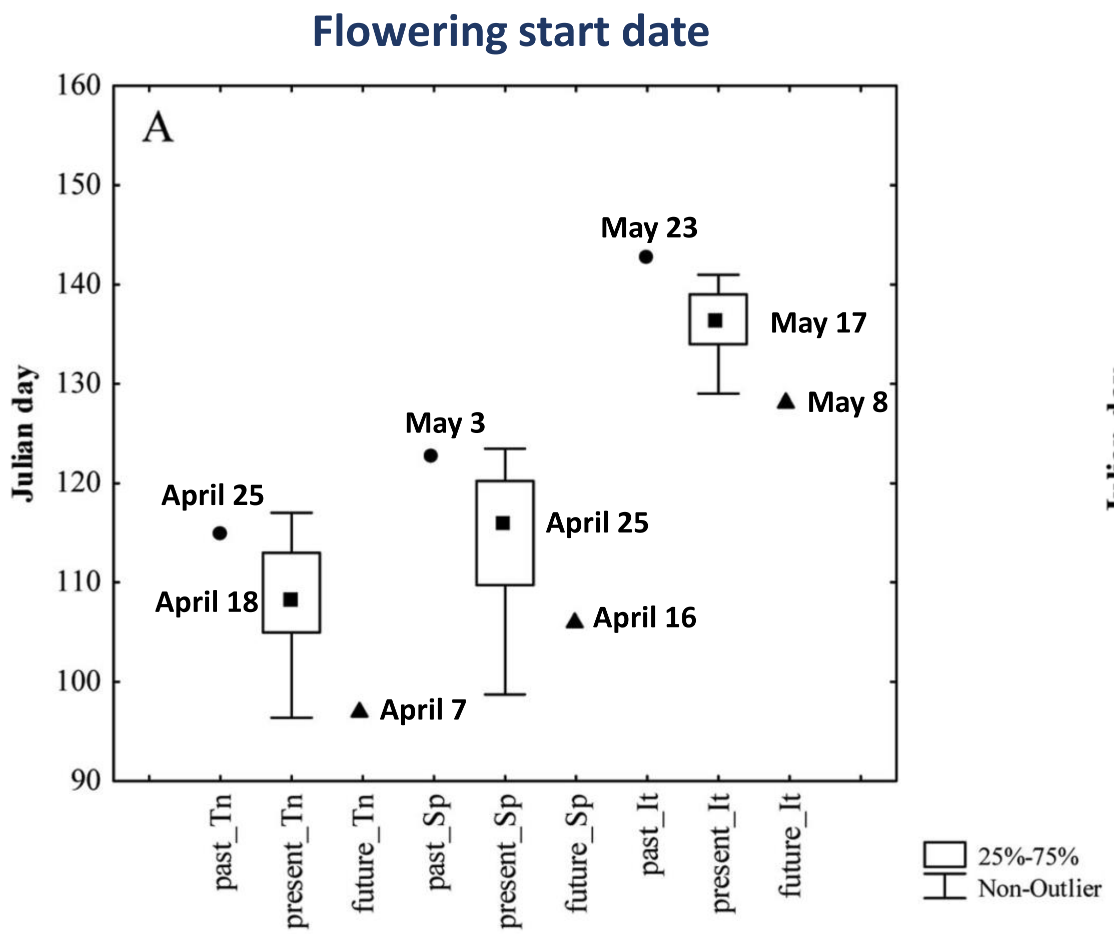
The full cross validation method for comparing the observed and expected values ranged in the different national and global areas:

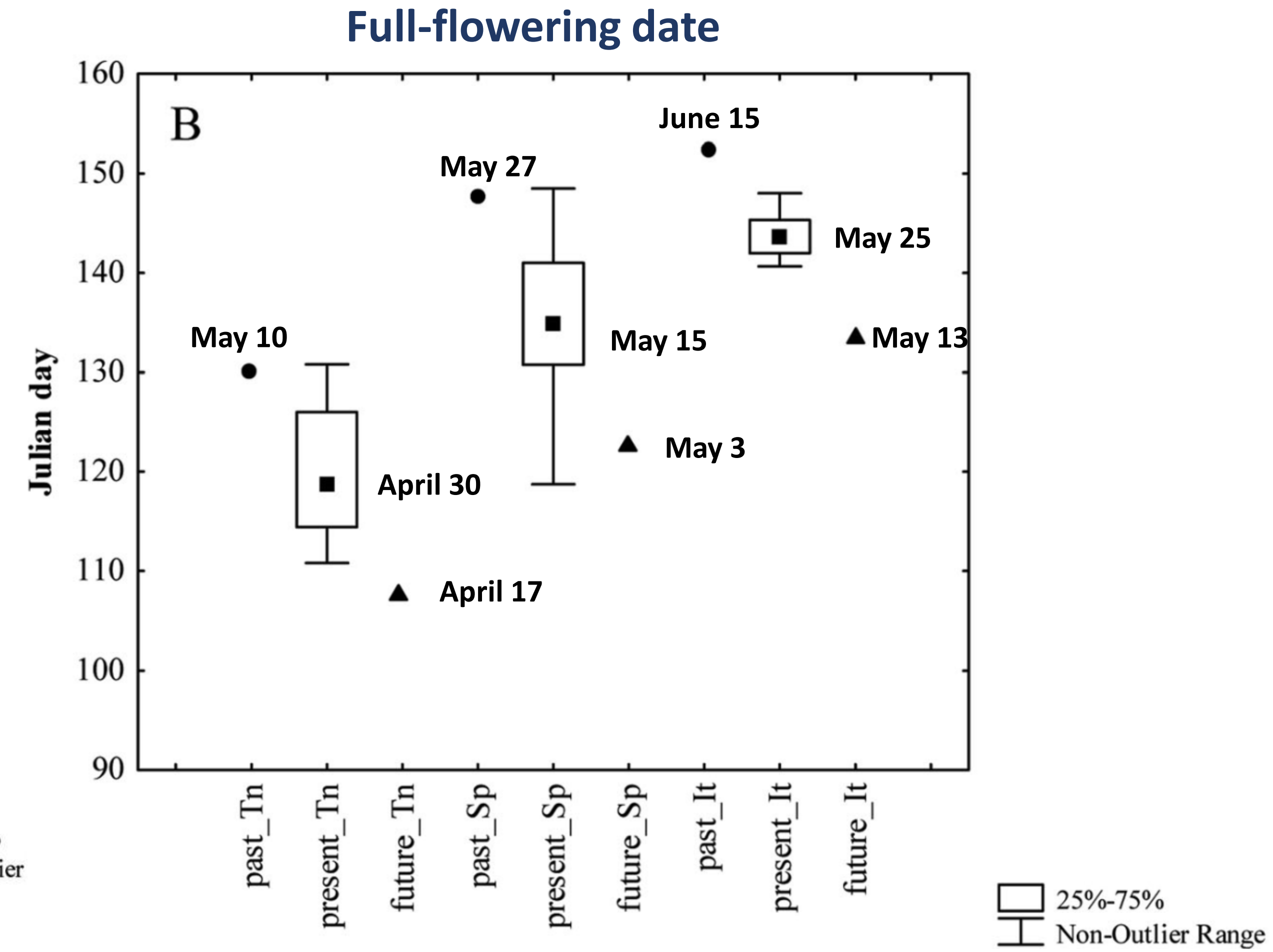
- From 1 to 7 % for the predictions for the flowering start dates,
- From 1 to 5 % for the predictions for the full-flowering dates

Aguilera et al 2015. *Int J Biometeorol*

Flowering date projections

Predictions of the average flowering start and full-flowering dates for both the past and the future periods. Tn Tunisia, Sp Spain, It Italy.





The period from 1961 to 1980 was used as the reference past period; the A1B emission scenario for the period 2081 to 2100

The mean anticipation of flowering start and full flowering for the future period was estimated at 10 and 12 days, respectively.

Aguilera et al 2015. *Int J Biometeorol*

Thank you very much!