From fossil pollen to climate: preliminary quantitative climate reconstructions for the last 3ky in northern Italy

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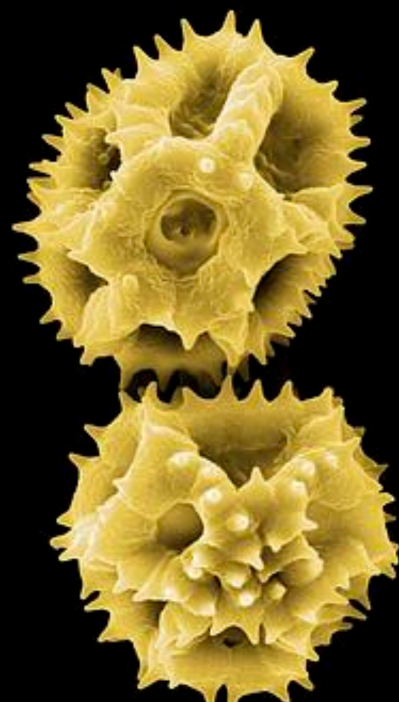

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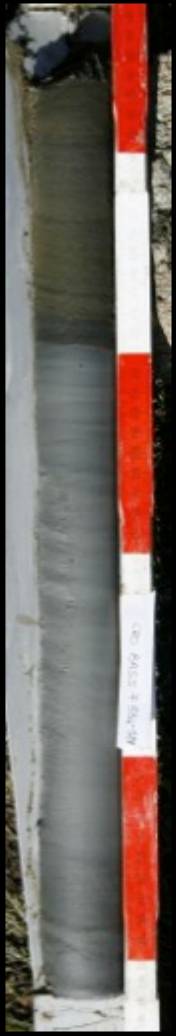
Project of Interest NextData
Work Package 1.5: Paleoclimate data from marine regions
Work Package 1.6: Paleoclimate data from continental regions



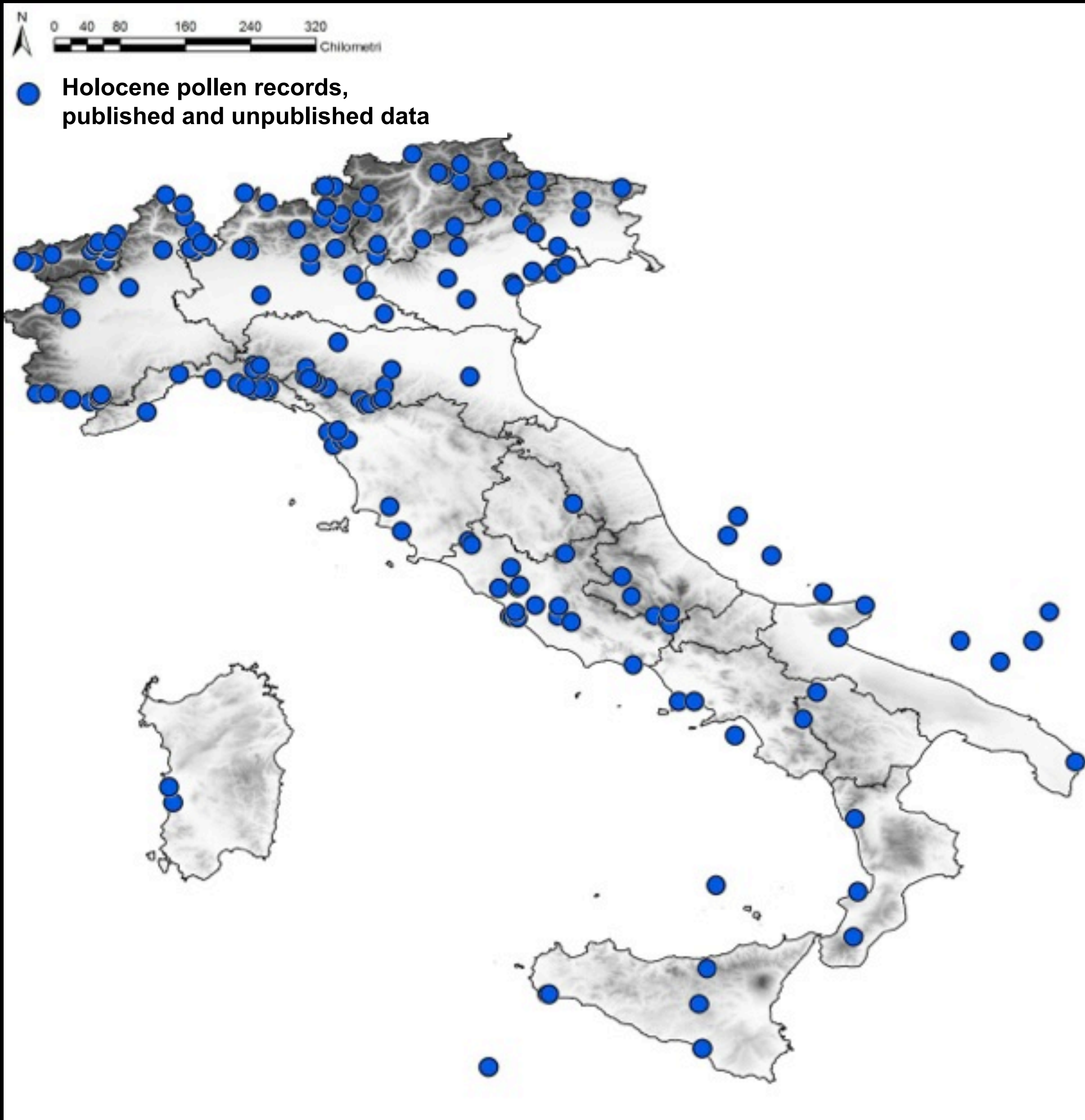
Collection and elaboration of pollen data from marine and terrestrial sedimentary archives for the last 3 ky

Aims:

- ❑ **Check the availability of pollen data for the last 3k**
- ❑ **Set up a database - data repository and tool to address future researches**
- ❑ **Reconstruction of the patterns of plant species distribution and past ecosystems structure through pollen data (*see Magri et al., RPP in press*)**
- ❑ **Provide quantitative paleoclimate estimations to be used for the multiproxy "Italy 2k" reconstructions**

Institutions involved:

- ❑ **University of Milano – Bicocca, Dept. of Environmental and Earth Sciences**
- ❑ **CNR – Institute for the Dynamics of Environmental Processes**
- ❑ **University "La Sapienza", Dept. of Environmental Biology**



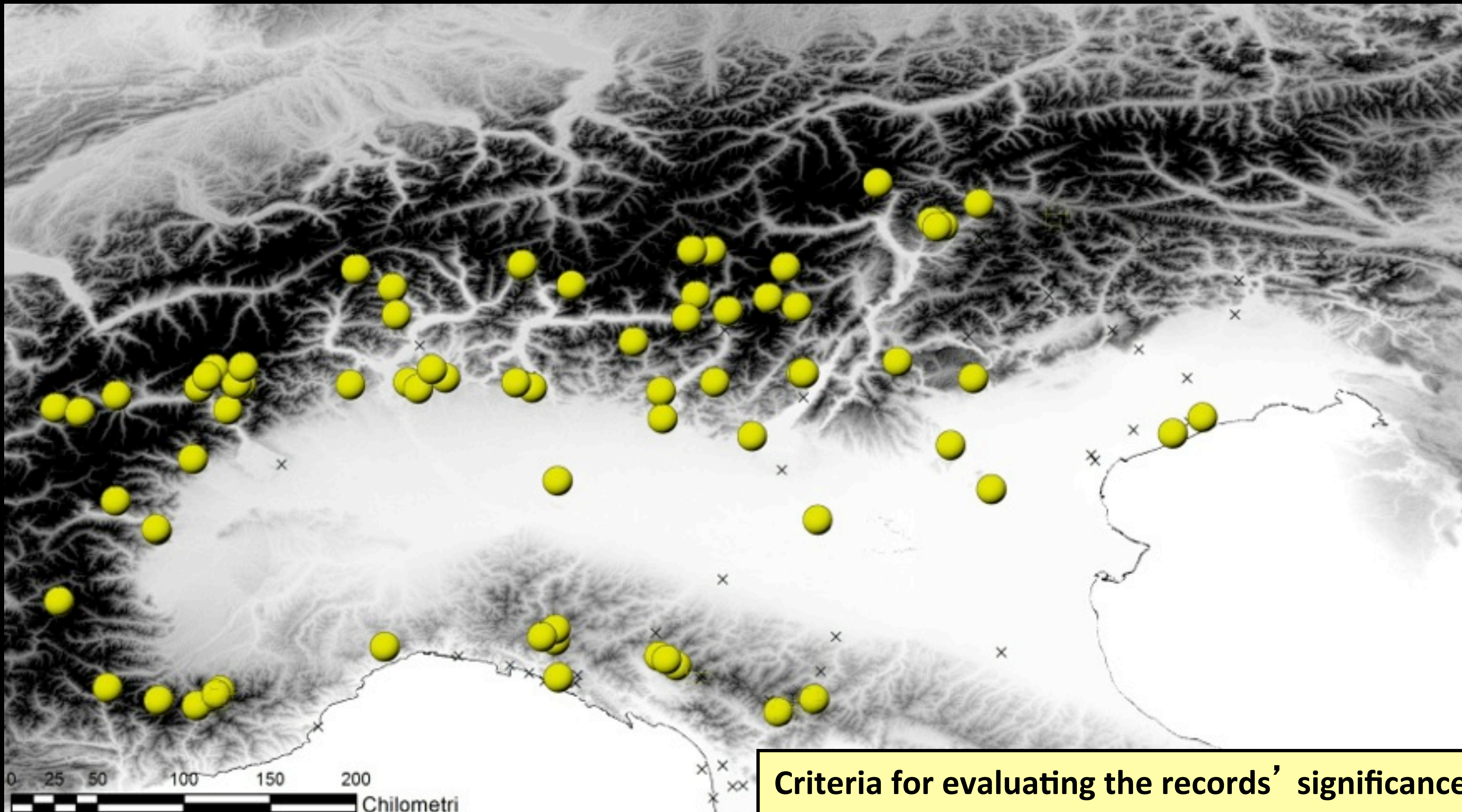
State-of-the art of palynological records available in Italy: general informations

- **211 sites**
(199 continental, 12 marine)

- all **altitudinal belts** are represented

- uneven site distribution

Holocene pollen records from continental and marine successions

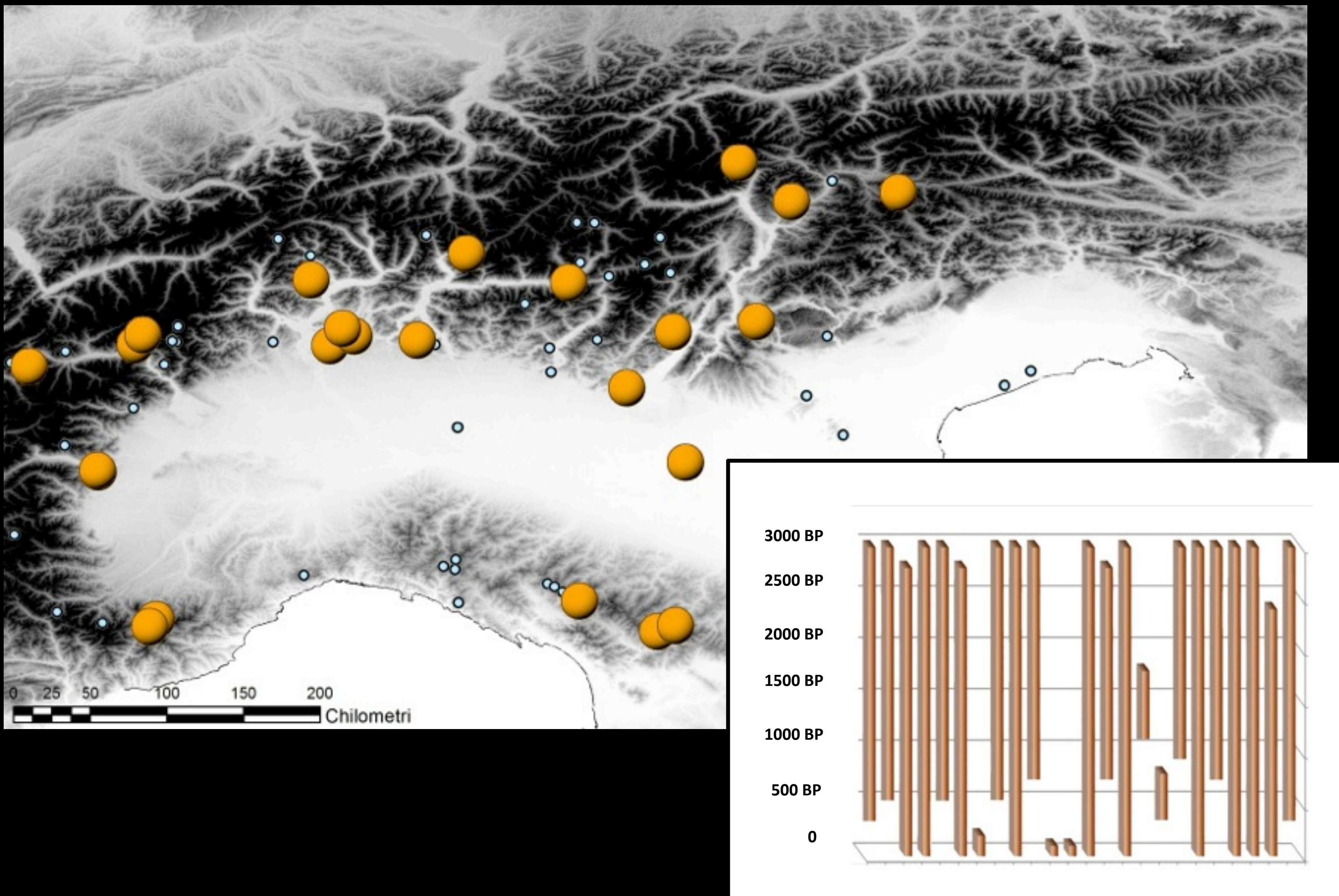


Pollen records documenting the last 3 ky obtained from lacustrine-palustrine successions in Northern Italy

Criteria for evaluating the records' significance:

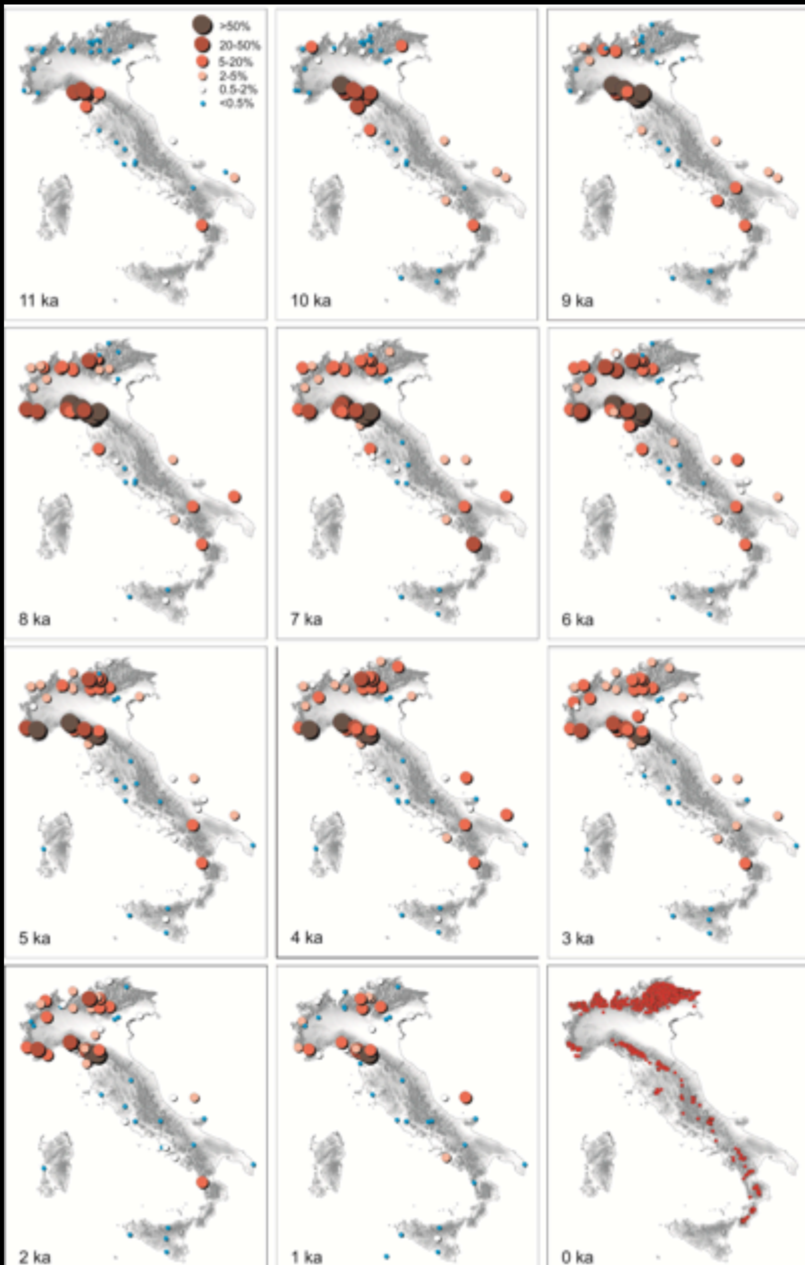
- ✓ **chronological robustness (available ^{14}C ages)**
- ✓ **chronostratigraphic resolution (less than one hundred years)**
- ✓ **comparability with the regional biostratigraphic model**

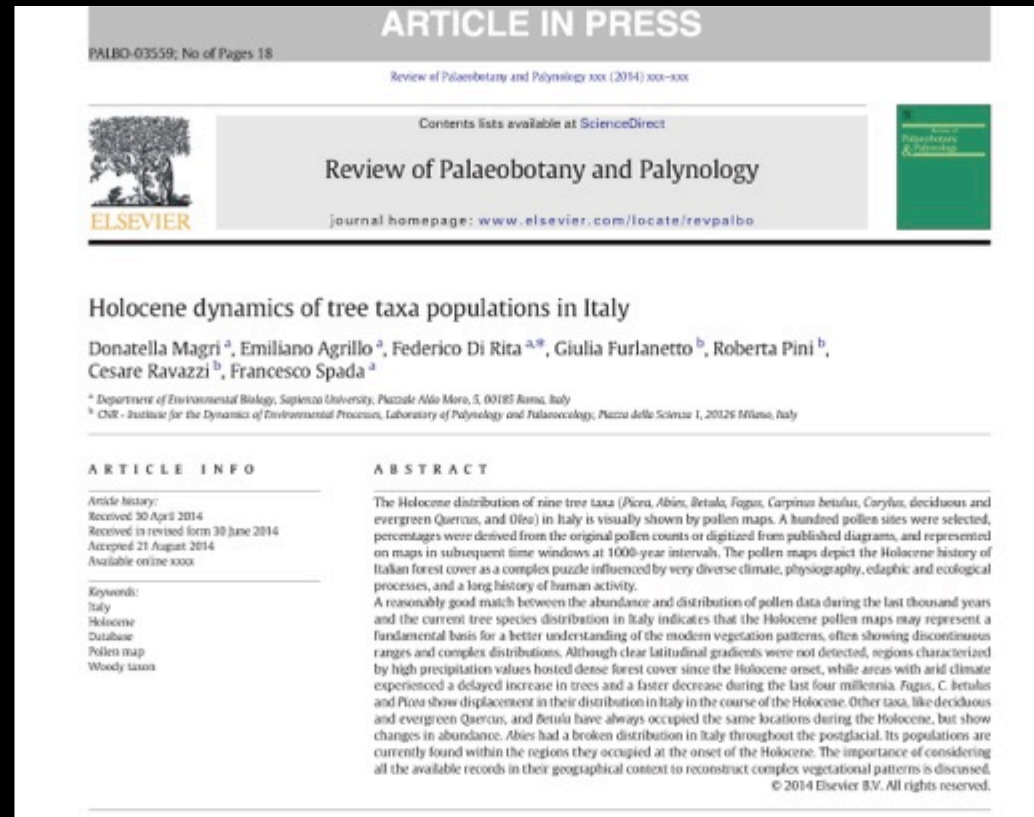
N-Italy BEST pollen datasets



Using pollen data to trace past distribution and dynamics of tree taxa

Abies





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Holocene dynamics of tree taxa populations in Italy

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ABSTRACT

The Holocene distribution of nine tree taxa (*Picea, Abies, Betula, Fagus, Carpinus betulus, Corylus,* deciduous and evergreen *Quercus,* and *Olea*) in Italy is visually shown by pollen maps. A hundred pollen sites were selected, percentages were derived from the original pollen counts or digitized from published diagrams, and represented on maps in subsequent time windows at 1000-year intervals. The pollen maps depict the Holocene history of Italian forest cover as a complex puzzle influenced by very diverse climate, physiography, edaphic and ecological processes, and a long history of human activity.

A reasonably good match between the abundance and distribution of pollen data during the last thousand years and the current tree species distribution in Italy indicates that the Holocene pollen maps may represent a fundamental basis for a better understanding of the modern vegetation patterns, often showing discontinuous ranges and complex distributions. Although clear latitudinal gradients were not detected, regions characterized by high precipitation values hosted dense forest cover since the Holocene onset, while areas with arid climate experienced a delayed increase in trees and a faster decrease during the last four millennia. *Fagus, C. betulus* and *Picea* show displacement in their distribution in Italy in the course of the Holocene. Other taxa, like deciduous and evergreen *Quercus,* and *Betula* have always occupied the same locations during the Holocene, but show changes in abundance. *Abies* had a broken distribution in Italy throughout the postglacial. Its populations are currently found within the regions they occupied at the onset of the Holocene. The importance of considering all the available records in their geographical context to reconstruct complex vegetational patterns is discussed.

distribution maps of nine tree taxa (*Picea, Abies, Betula, Fagus, Carpinus betulus, Corylus,* deciduous and evergreen *Quercus,* and *Olea*) in subsequent time windows from 11 ka to present

Pollen as paleoclimate proxy

potential for quantitative paleoclimate estimations not yet been fully explored and understood. As vegetation integrates the climate signal over a number of years, plant assemblages can be used for climate classification and introduction of schemes of greater and lesser complexity into climate modelling (Hay, 2013).

Basic biological assumptions

Pollen is a function of regional vegetation

--> Regional vegetation is a function of climate

---> Pollen is an indirect function of climate and can be used to reconstruct past regional climate

A three-step approach (Juggins and Birks 2012):

(i) the development of modern pollen-vegetation-climate training sets, to fully understand the relationships between pollen rain, plant distribution and climate

→ accuracy and reliability of reconstructions depend on the size, coverage and quality of the training set!

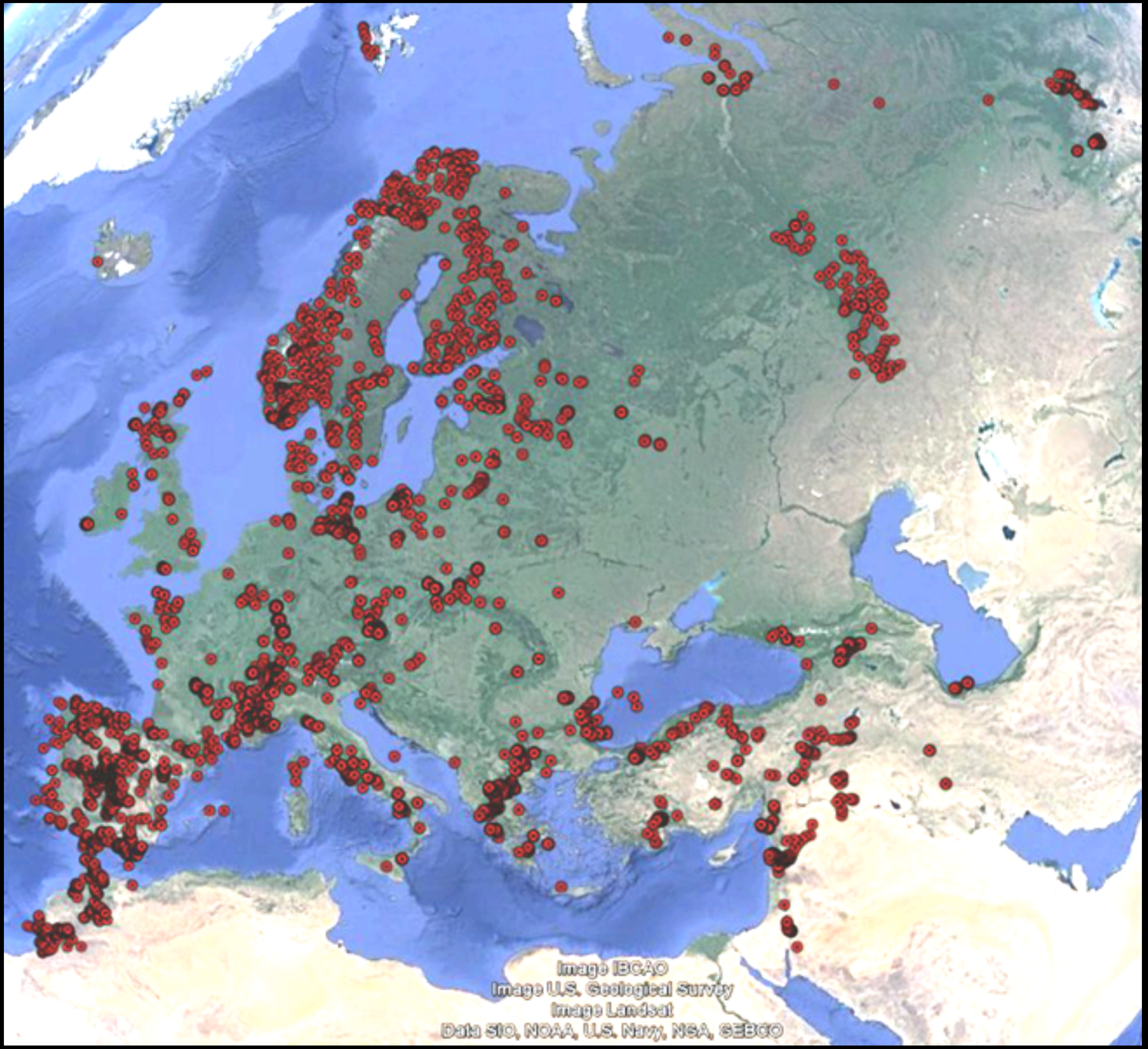
(ii) the application of numerical techniques to the training sets, to model the relationships between pollen-vegetation occurrences and environmental conditions

(iii) the application of this model to pollen-stratigraphical data

(i) the development of modern pollen-vegetation-climate training sets: the EMPD – European Modern Pollen Database

Training set of modern pollen and climate data from nearly 4800 sites across Europe and part of N-Africa (Davis et a., 2013)

Here used as a training set for comparison with fossil pollen spectra and elaboration of paleoclimate transfer functions

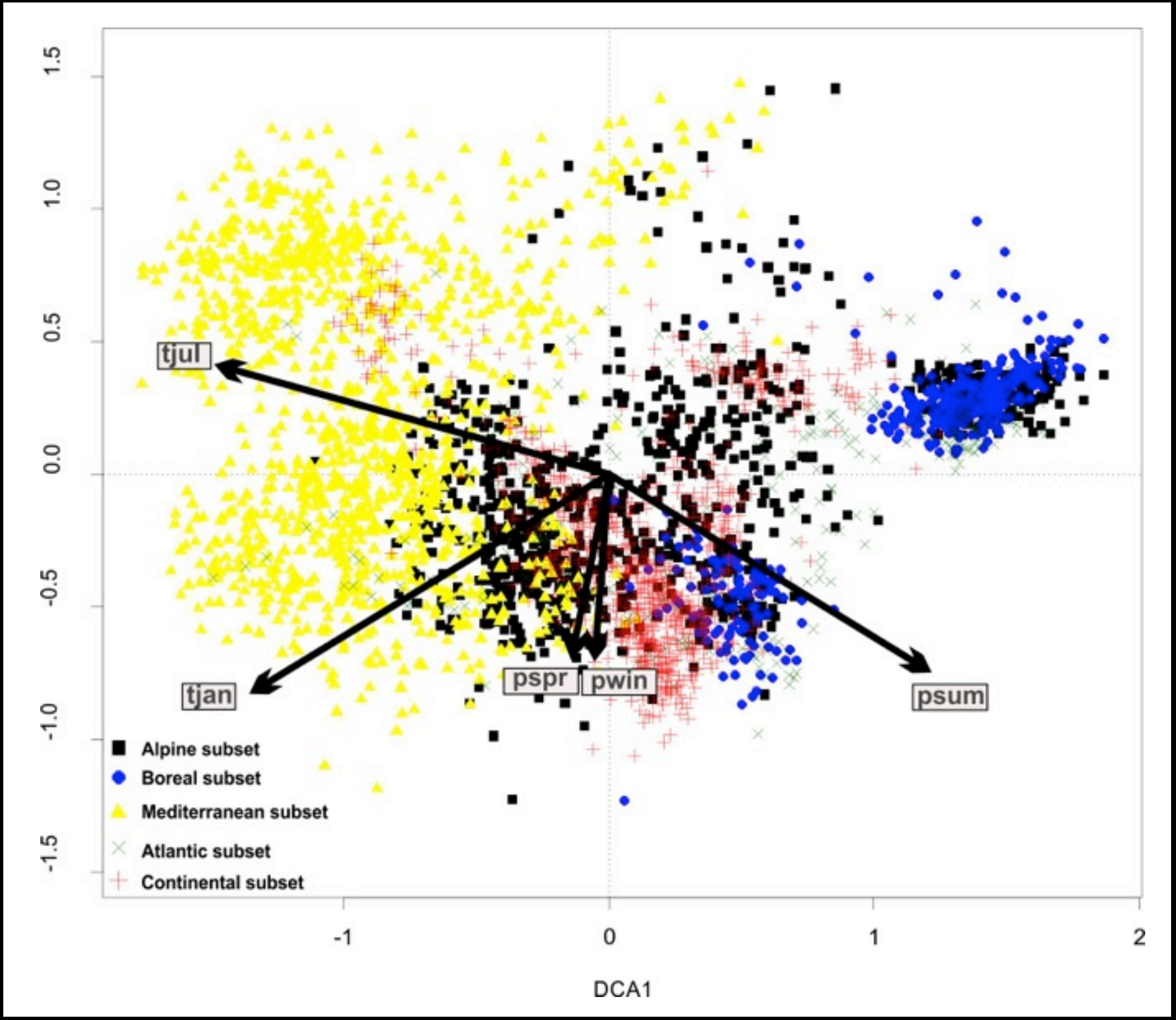


(i) the development of modern pollen-vegetation-climate training sets: the EMPD – European Modern Pollen Database

DCA of the whole EMPD training set

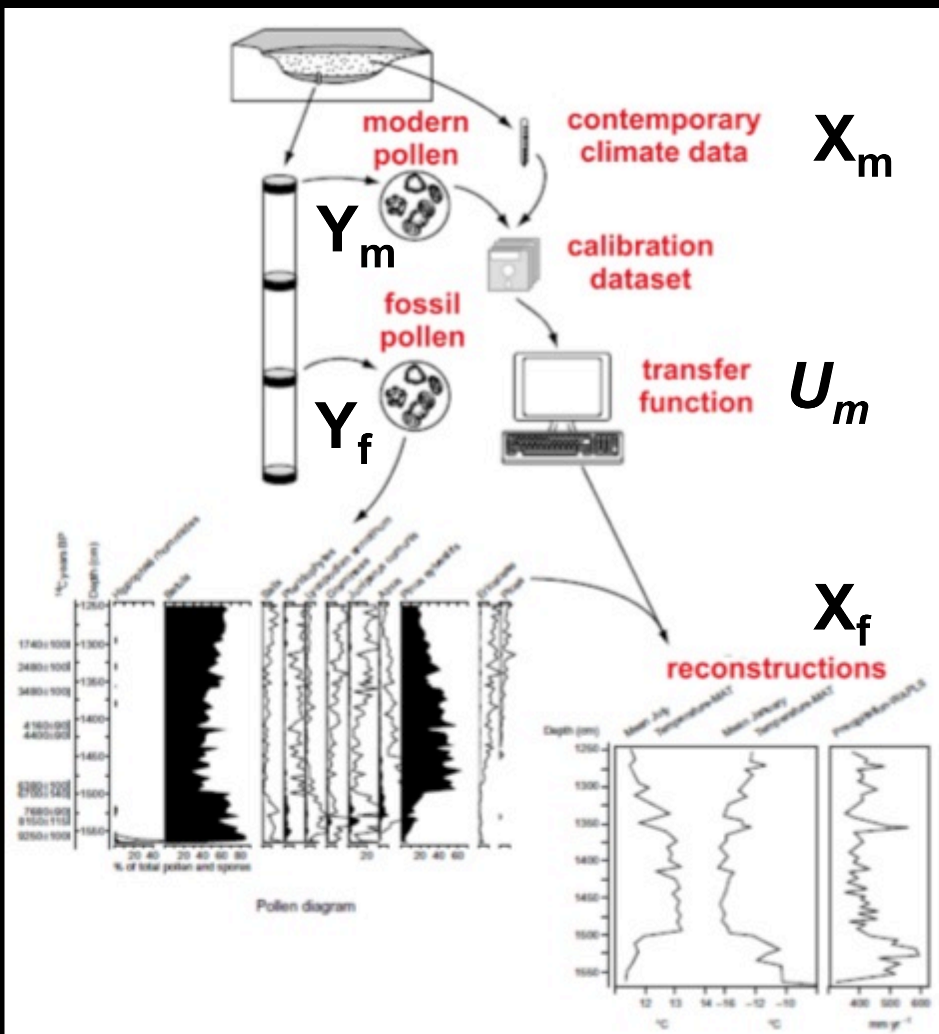
Biogeographical regions according to the EEA (European Environment Agency)

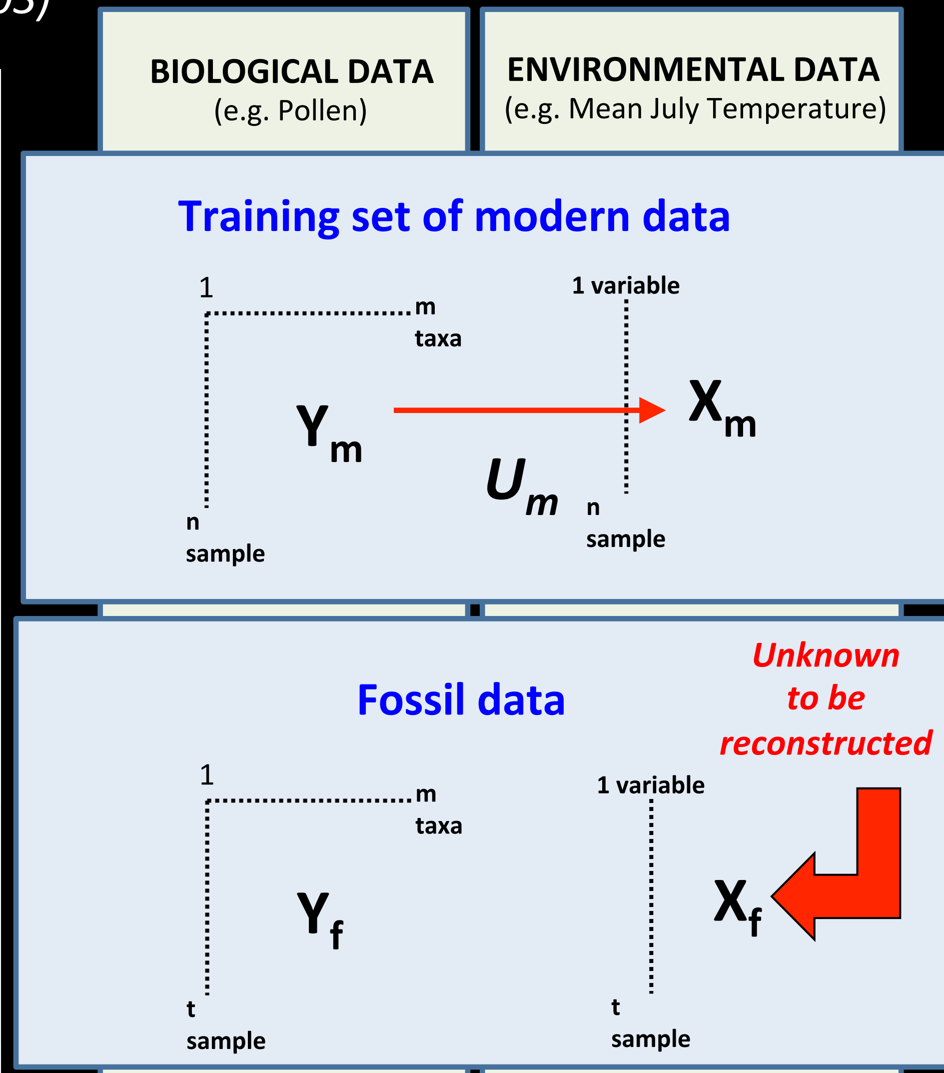
Climatic interpretation through the EnvFit function (R software)



(ii) the application of numerical techniques and the development of transfer functions

*"The modern relationships between **Y** and **X** are modelled numerically and the resulting transfer function is used to transform the fossil data $\boldsymbol{Y_0}$ into quantitative estimates of the past environmental variable(s) ($\boldsymbol{X_0}$)" (Birks 2003)*





(ii) the application of numerical techniques to pollen data: three main approaches

wMAT = weighted Modern Analogue Technique

similarity/dissimilarity coefficients (square chord distance) are used to find k- analogues of each fossil pollen sample in the modern training set. Values of environmental variables are then calculated as weighted means from the K-analogues.
Number of useful k analogues defined in cross-validation (usually 5).

LWWA = Locally Weighted Weighted Averaging

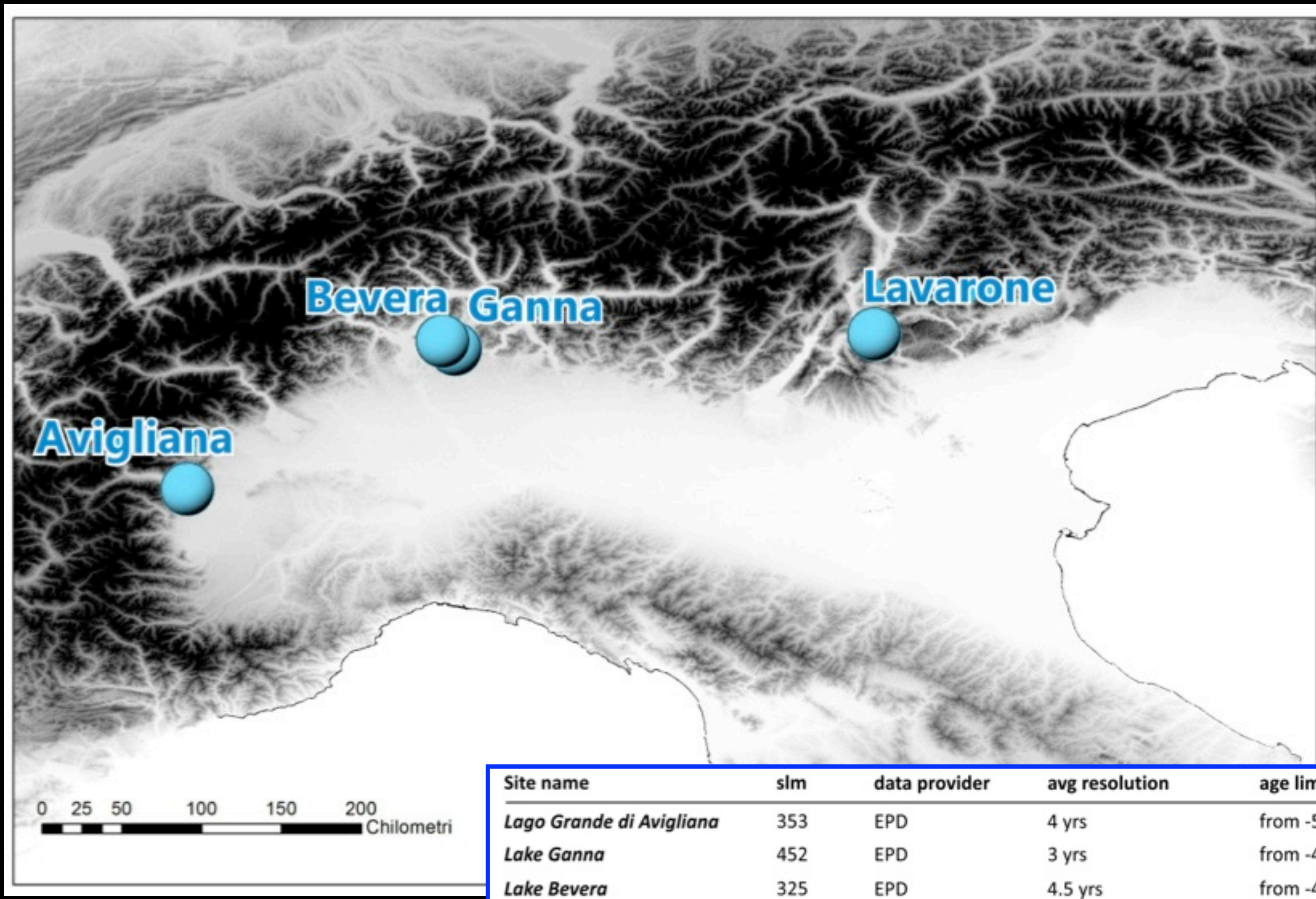
similar to MAT, but larger number of analogues is taken into account (30-40).
Environmental optima and tolerances are then estimated by weighted mean of the values expressed by the k analogues.
This method is based on dynamic traing sets: for each pollen sample, calibration methods are applied to the nearest k analogues.

LWWA-PLS = Locally Weighted Weighted Averaging Partial Least Square

Similar to LWWA. Principal components are searched for to reduce collinearity effects.

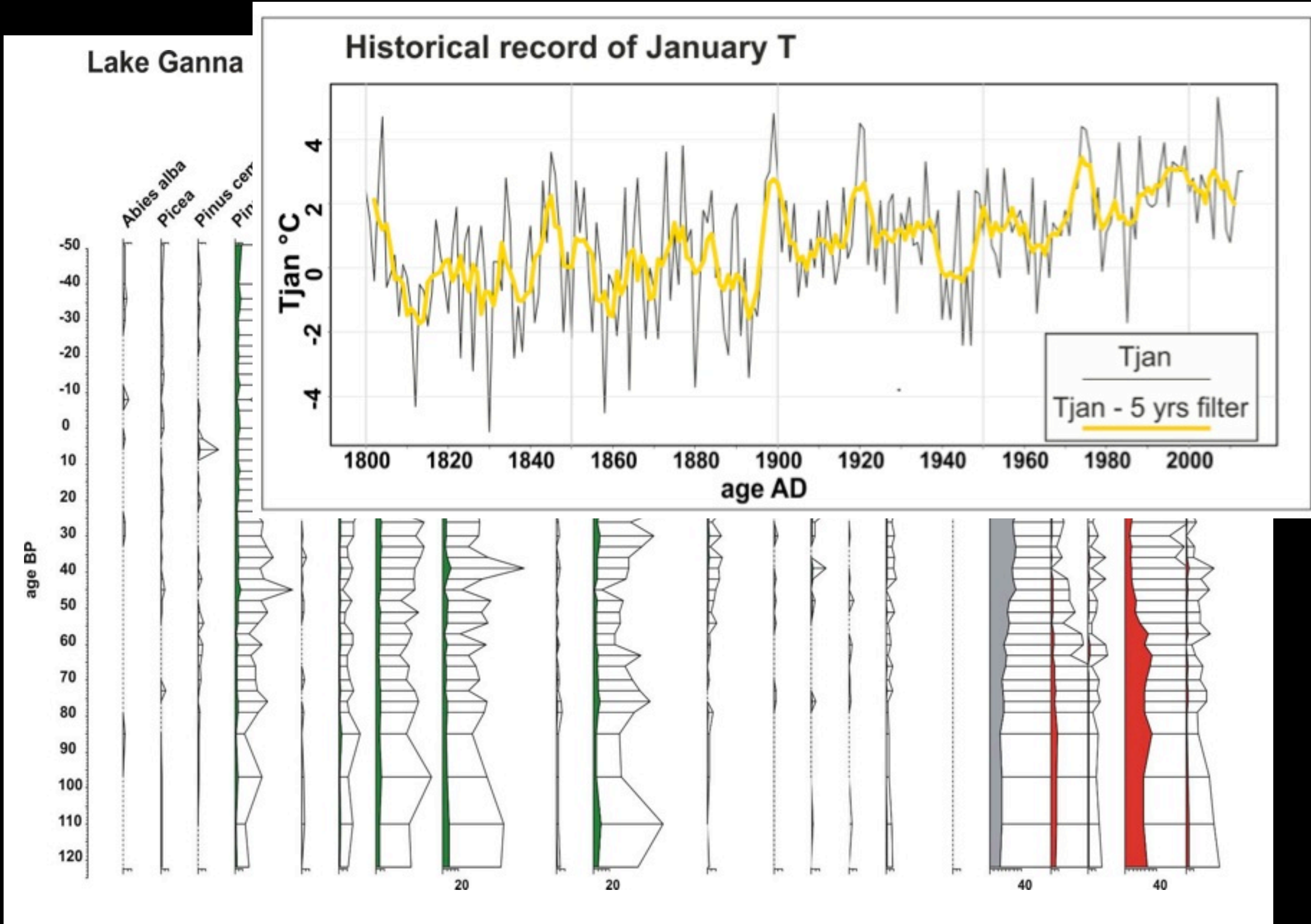
(iii) testing pollen transfer functions: the 0 – 200 y test

Late Holocene pollen-inferred T series compared with T instrumental records from the same sites (kindly provided by M. Brunetti, ISAC-CNR)

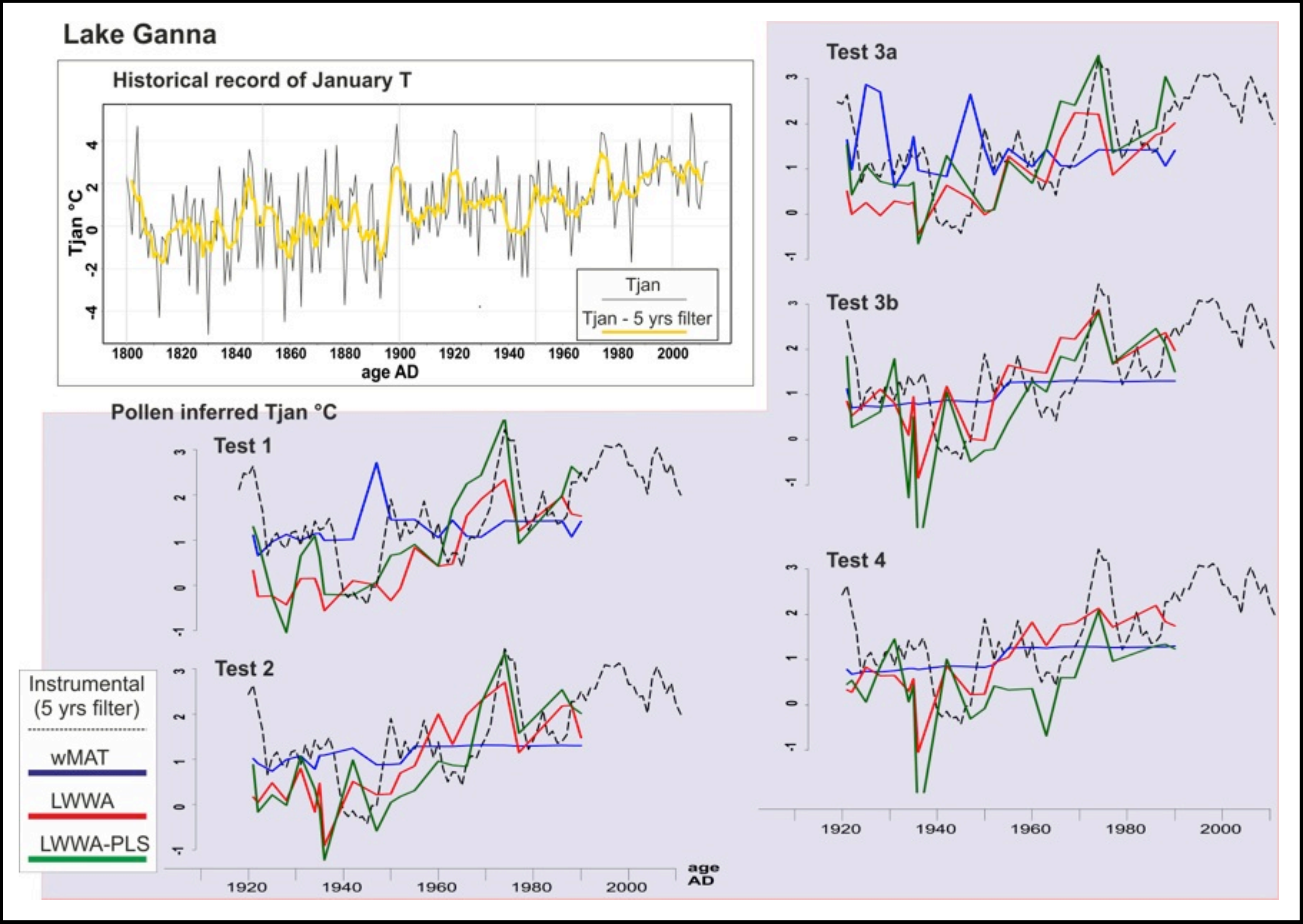


Site name	slm	data provider	avg resolution	age limit
Lago Grande di Avigliana	353	EPD	4 yrs	from -51 to 122 BP
Lake Ganna	452	EPD	3 yrs	from -40 to 28 BP
Lake Bevera	325	EPD	4.5 yrs	from -40 to 10 BP
Lake Lavarone	1115	IDPA	9 yrs (last 0.2k)	from -51 to 143 BP

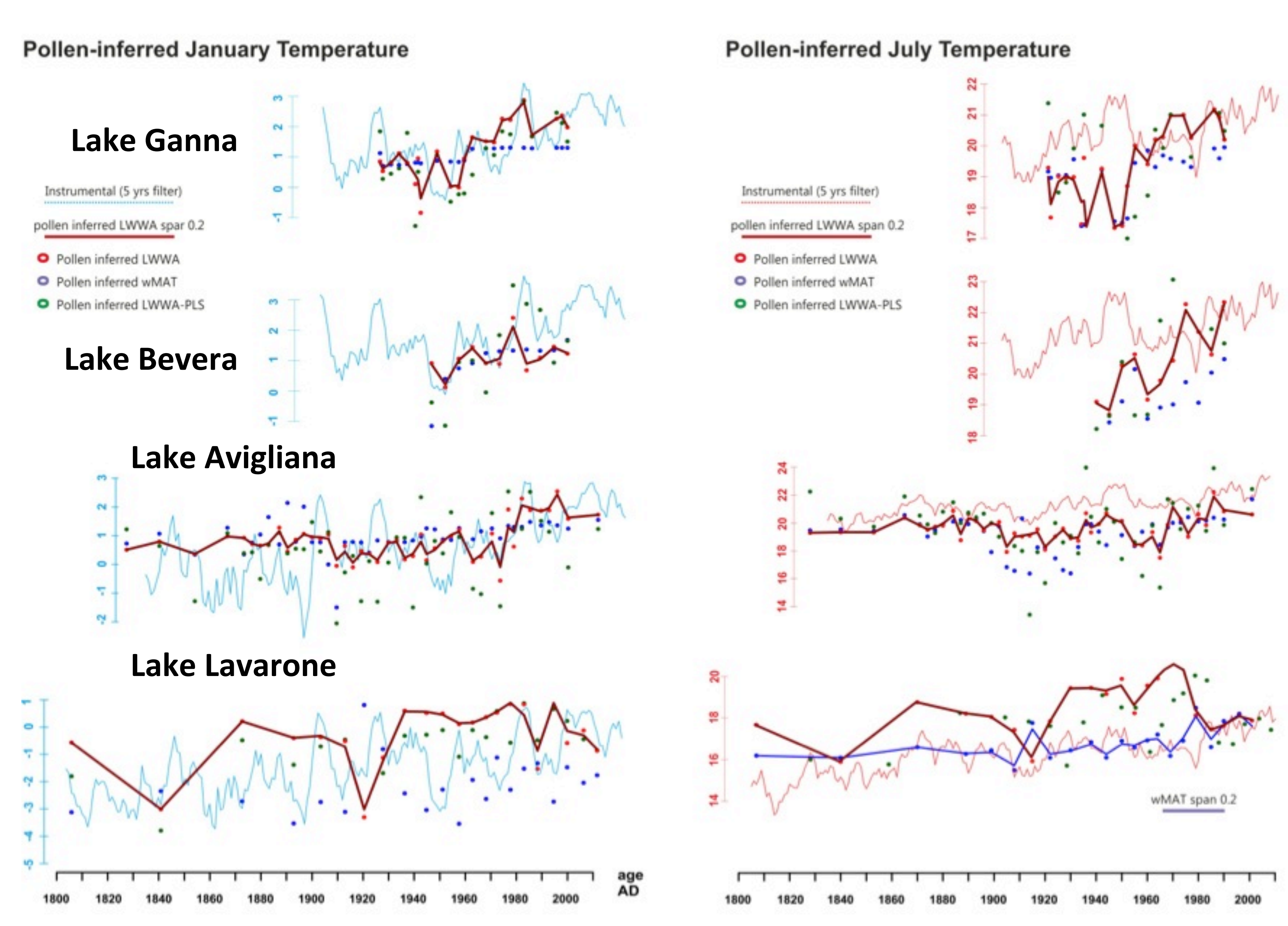
(iii) testing pollen transfer functions: the 0 – 200 y test



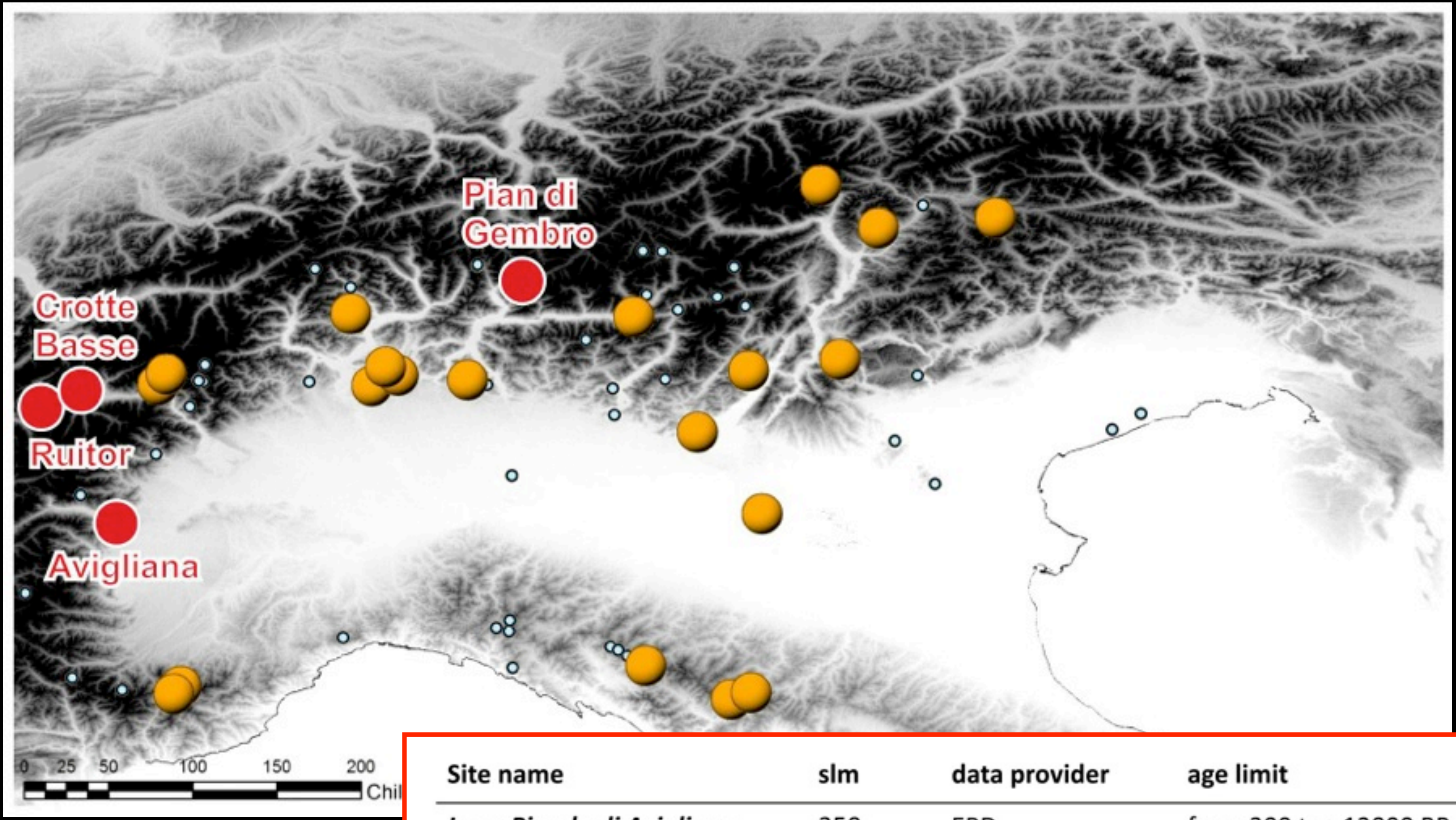
(iii) testing pollen transfer functions: Tjan at Lake Ganna



(iii) testing pollen transfer functions: Tjan and Tjuly at the four sites

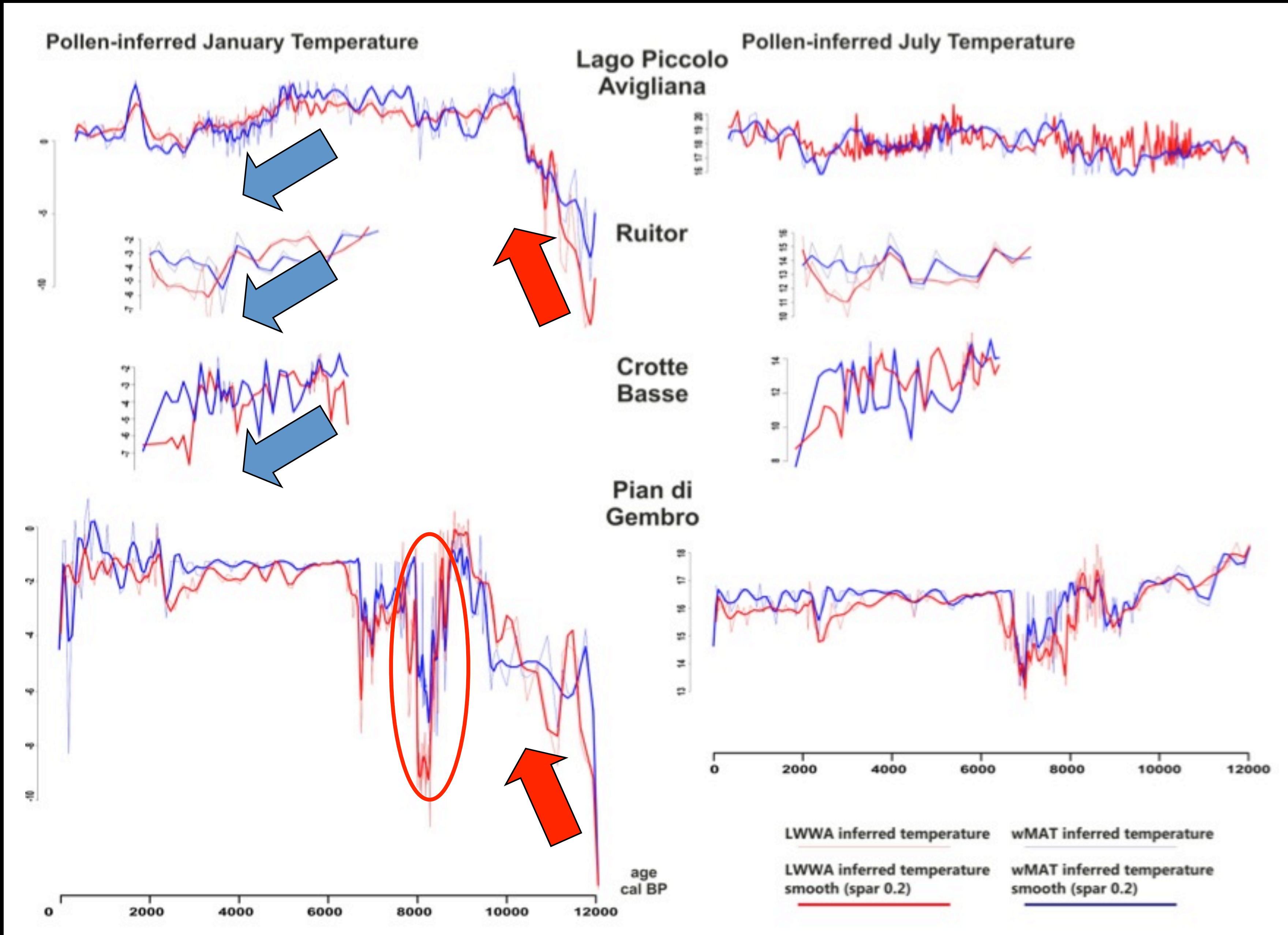


(iii) testing pollen transfer functions on long Holocene records

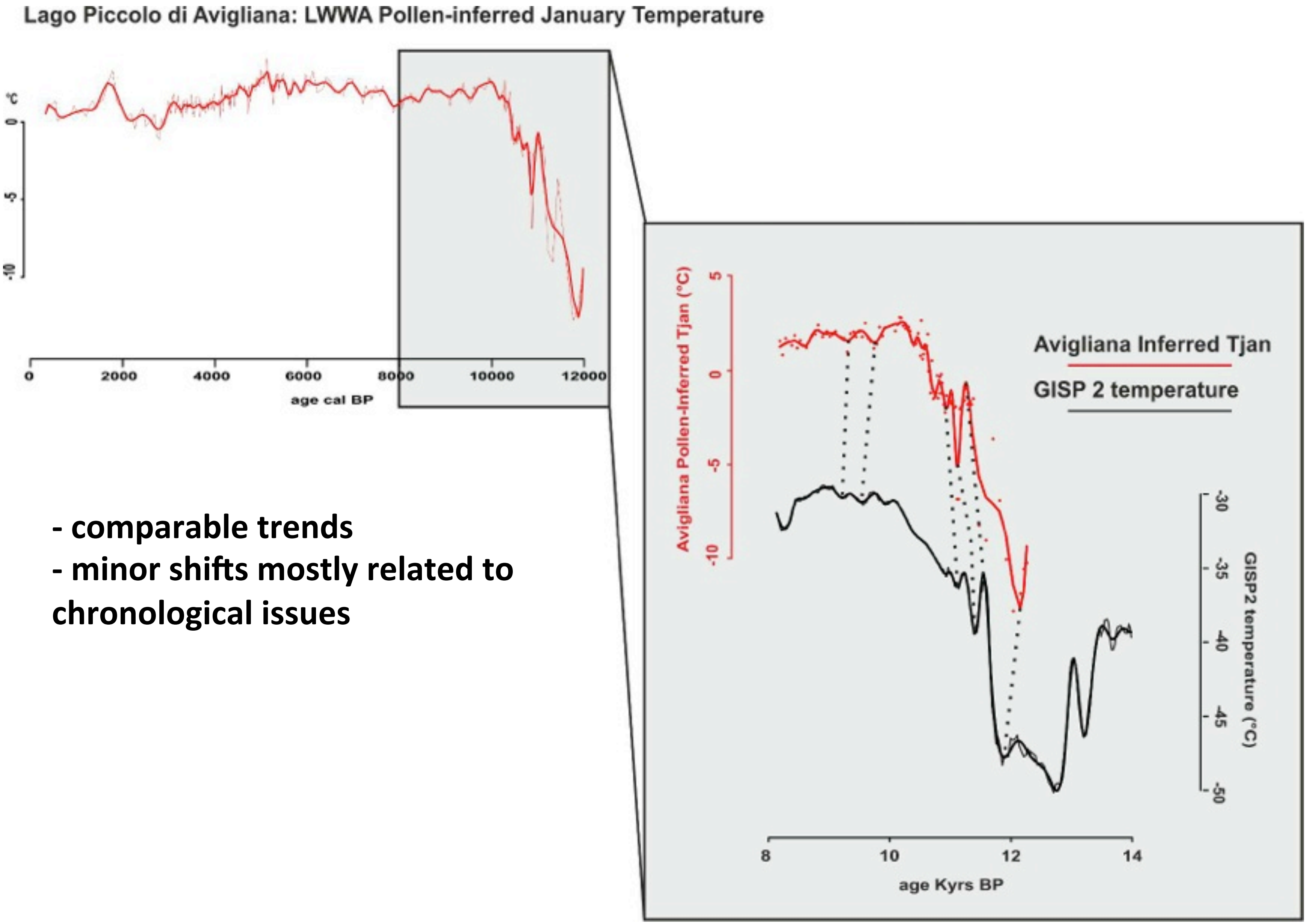


Site name	slm	data provider	age limit
Lago Piccolo di Avigliana	350	EPD	from 300 to >12000 BP
Ruitor - Torbiera Valter	2450	IDPA	from 2000 to 7000 BP
Crotte Basse	2362	IDPA	from 2000 to 6000 BP
Pian di Gembro	1350	IDPA	from -50 to >12000 BP

(iii) testing pollen transfer functions on long Holocene records

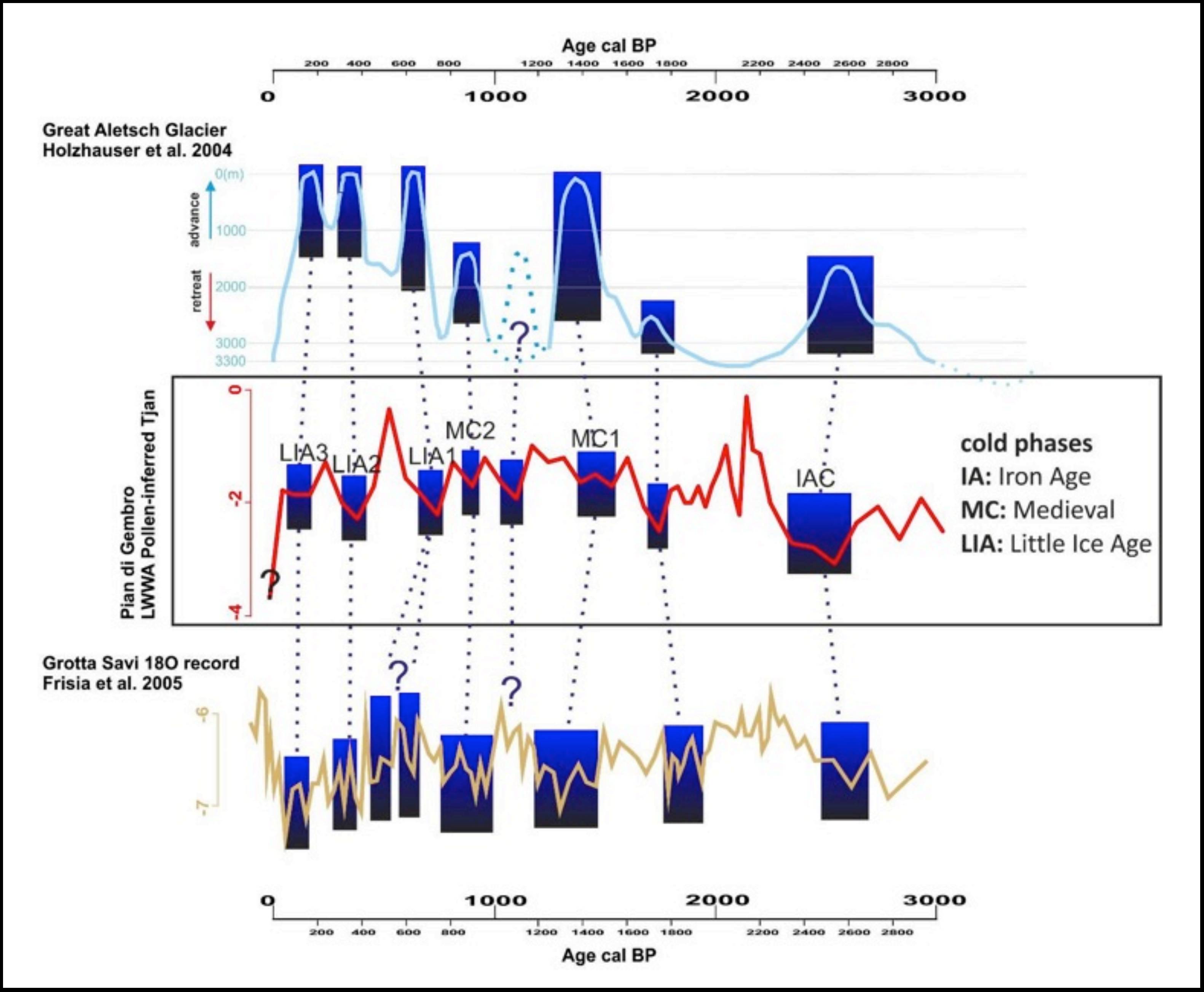


(iii) comparing different proxy-based reconstructions

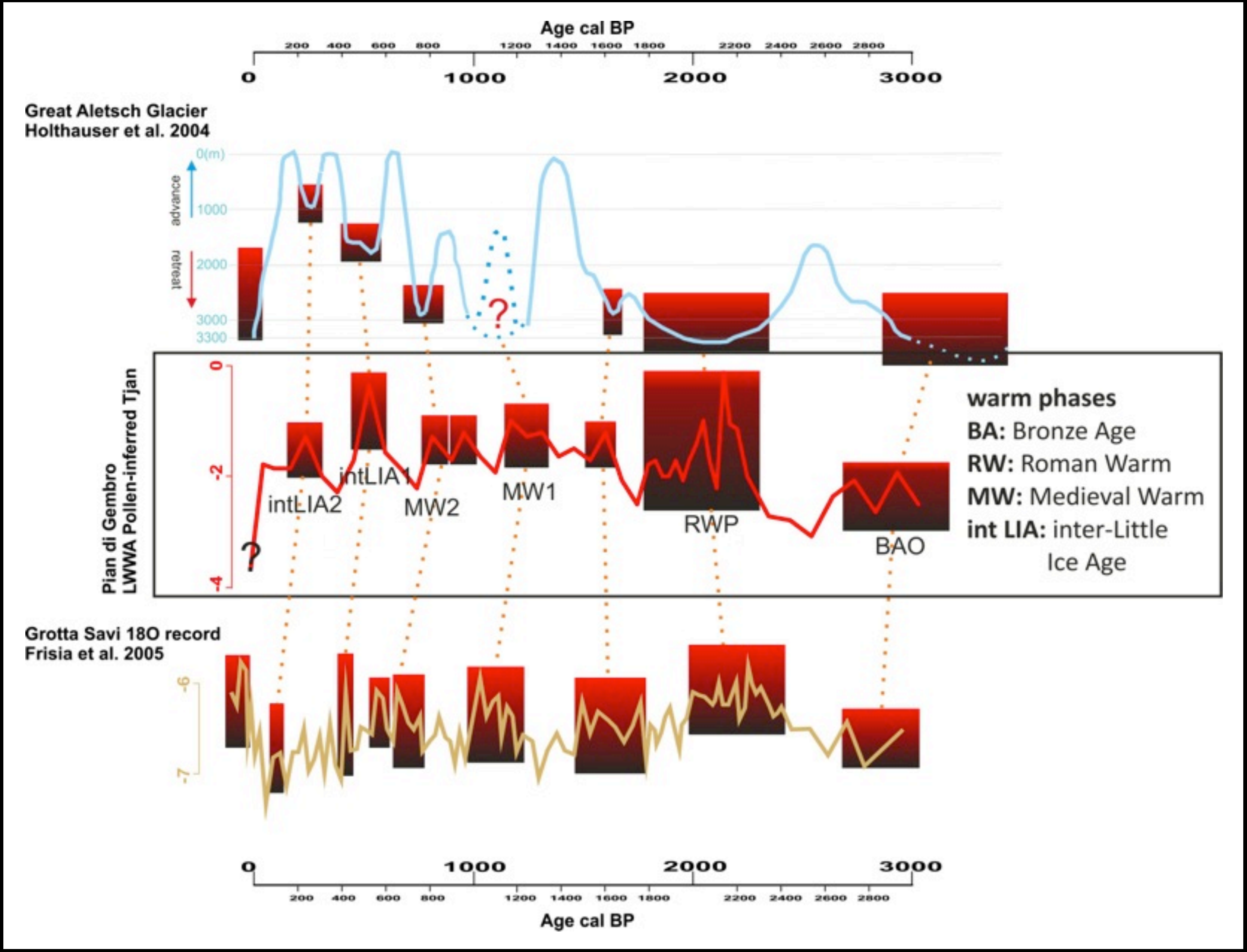


- comparable trends
- minor shifts mostly related to chronological issues

(iii) comparing independent paleoclimate reconstructions for cold periods



(iii) comparing independent paleoclimate reconstructions for warm periods



Conclusions

- Pollen data allow reconstruction of past patterns of plant distribution and dynamics, but what about climate history?

- statistical approaches applied to pollen records allow obtaining informations on past environmental variables (e.g. temperature), *via* the comparison with modern training sets

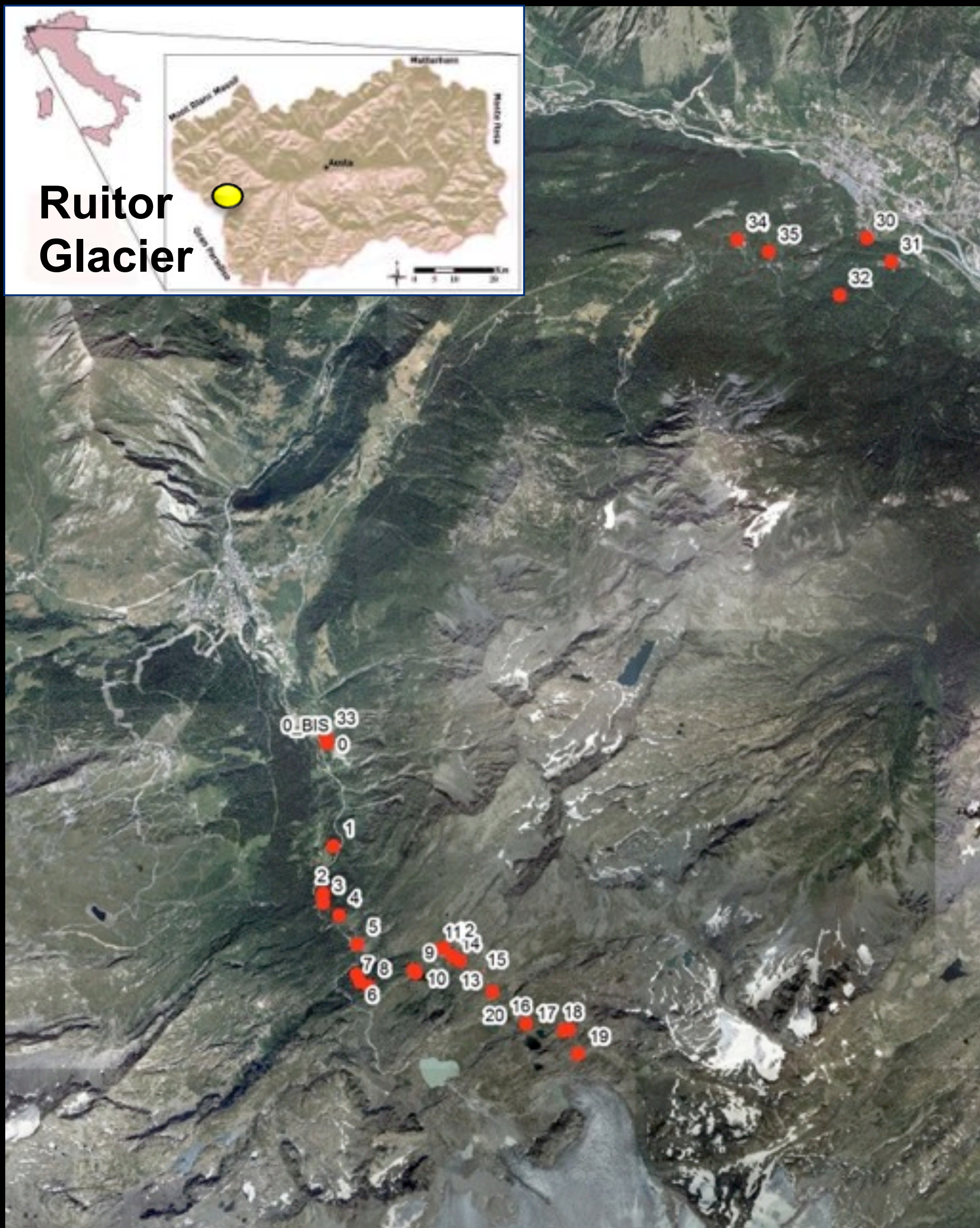
- tests on the last 200 years show positive comparison between pollen-inferred temperaure reconstructions and instrumental series

- the same approaches were then applied on longer Holocene sequences to retrieve the signal of climate variability along a wider time span

- increasing T at the Holocene onset, the 8,2 ka event, more stability up to 5,5 ka and then trend towards increasing climate oscillations and cooling

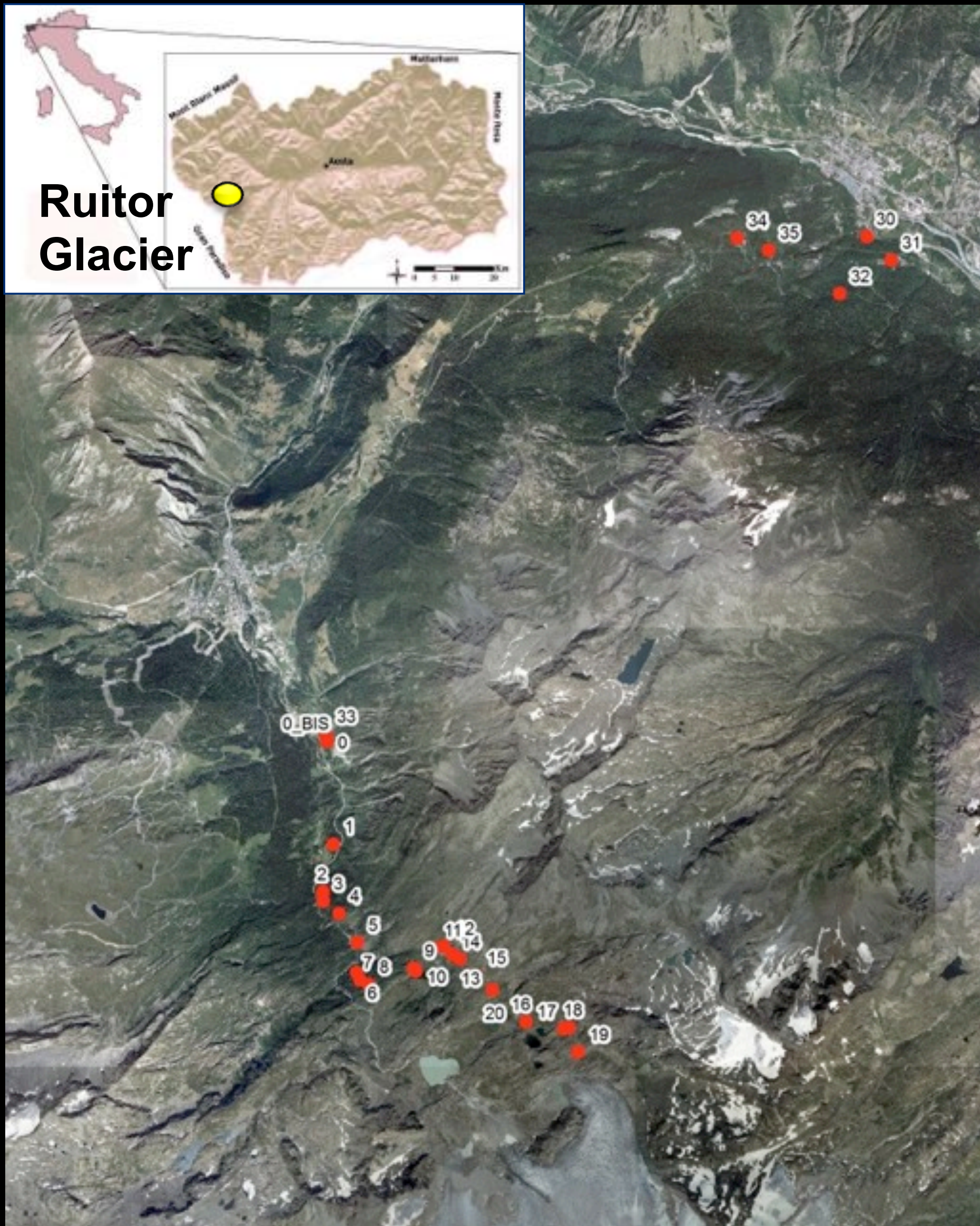
- issues when reconstructing climate parameters from high-altitude pollen records, due to the scarcity of taxonomically-accurate modern pollen analogues associated with climate data and problems with long-distance transport of pollen from lower altitudes

The development of a local altitudinal training set in the western Alps



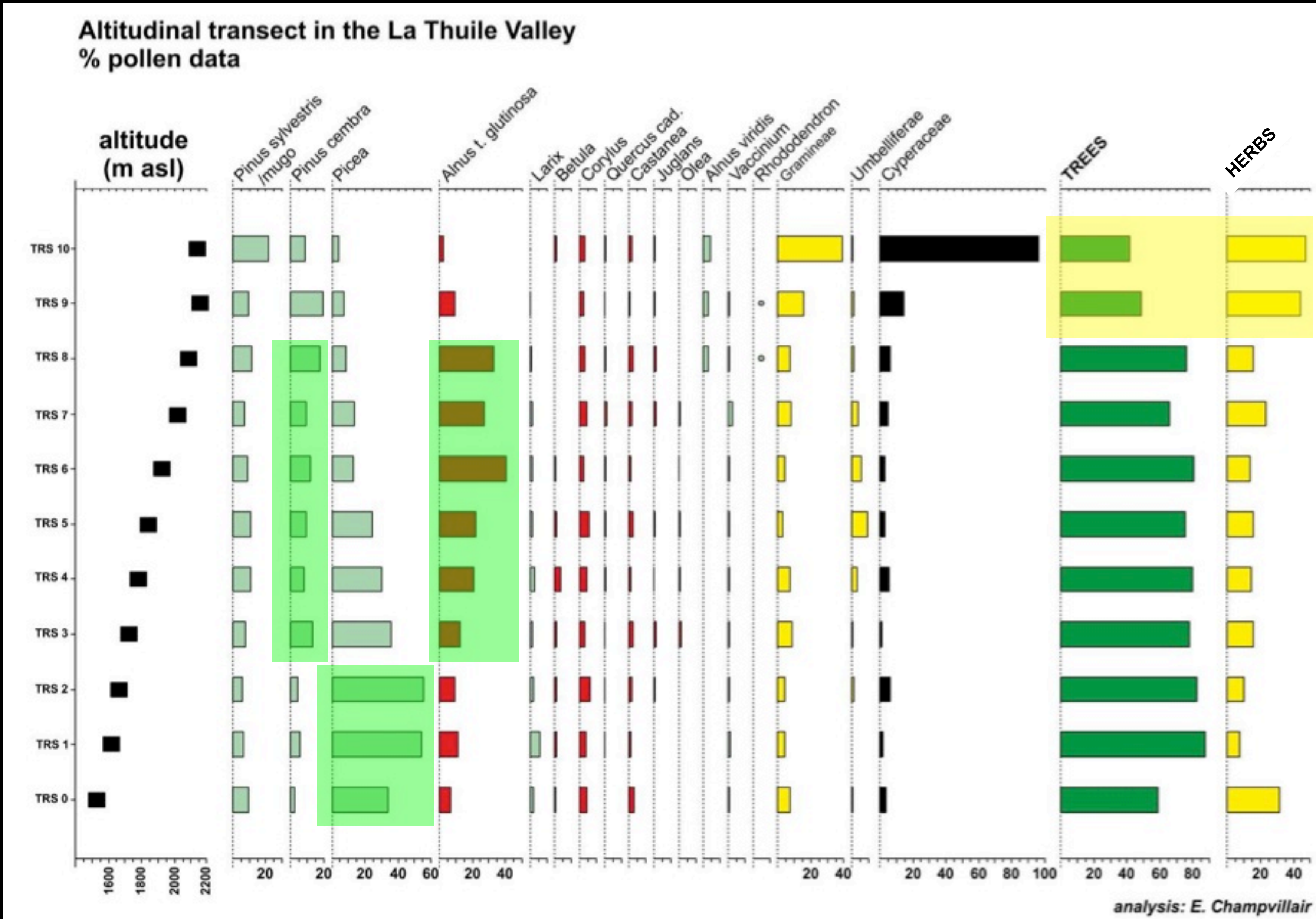
26 sampling sites
from 983 m asl (***site n°30***)
to 2668 m asl (***site n° 19***)

The development of a local altitudinal training set in the western Alps

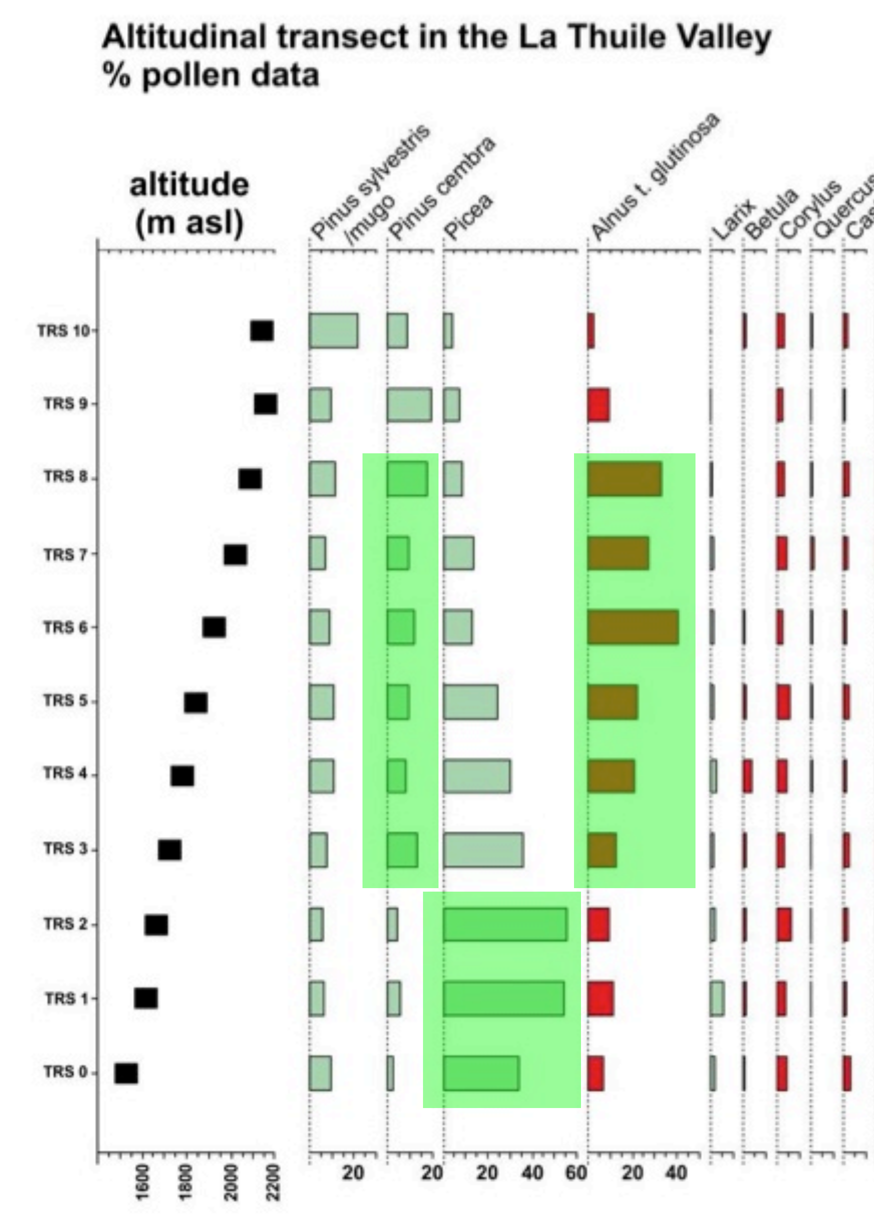


GPS positioning and
vegetation surveys
at different scales

First data on pollen rain along the altitudinal training set in the western Alps



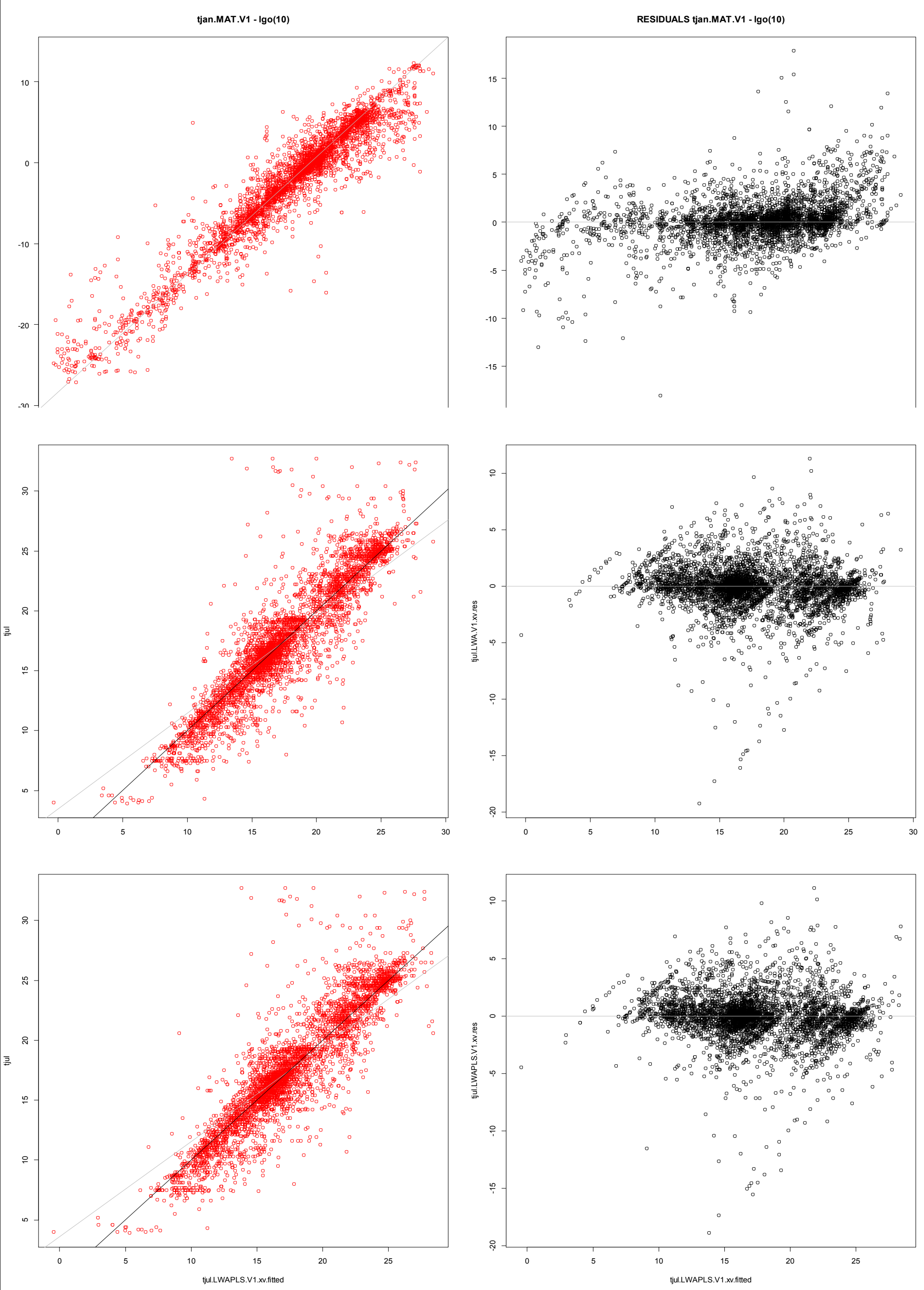
First data on pollen rain along the altitudinal training set in the western Alps



Thanks for your attention

(ii) the application of numerical techniques: three main approaches

Approach	Modern biological data (Y_m)	Link to the environmental variable (X_m)	References
Indicator-species approach	Presence/absence of one to very few taxa of known ecological requirements	Probability density functions	Iversen 1944 Conolly & Dahl 1970 Atkinson et al 1987 Kuhl et al 2002
Assemblage approach (MAT)	Presence/absence of several taxa	Modern analogue matching Response surface	Guiot 1990 Overpeck et al 1985 Thompson et al 2008 Bartelein et al 1986 Huntley 1993 Prentice et al 1991
Multivariate calibration-function approach (WA, WA PLS, LWWA, LWWA PLS)	Modern quantitative data from several sites	Linear/non linear regression and calibration	Imbrie & Kipp 1971 Birks et al 1990 Ter Braak & Juggins 1993



TEST 1

All taxa to genus level, except for *Pinus* and *Quercus*

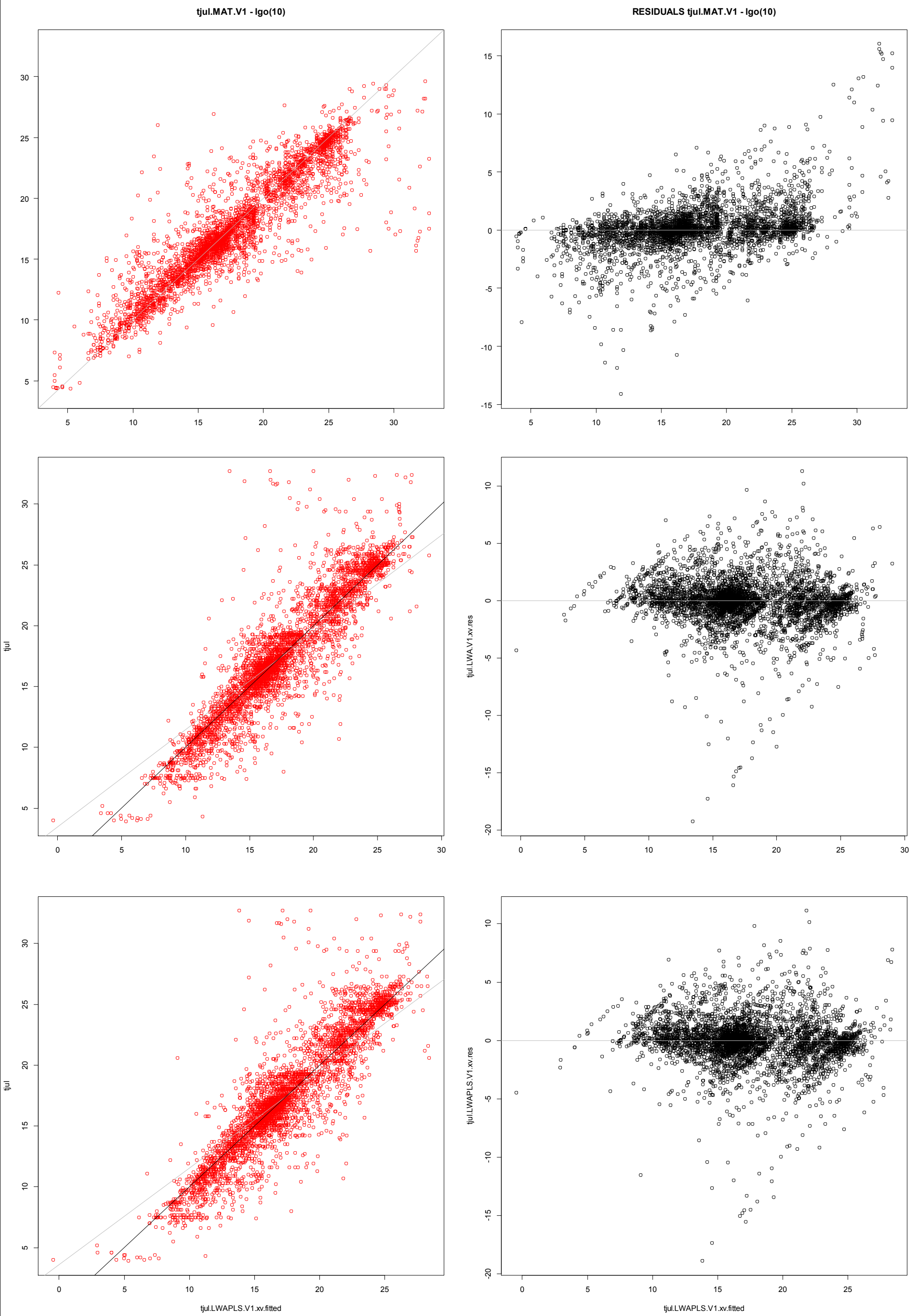
wMAT

LWWA

LWWA-PLS

Model	RMSE	RMSEP
MAT k2	2,15	2,18
MAT k3	2,12	2,15
MAT k4	2,15	2,19
MAT k5	2,16	2,2
wMAT k2	2,11	2,15
wMAT k3	2,05	2,09
wMAT k4	2,06	2,1
wMAT k5	2,09	2,1
LWWAinv	2,28	2,34
LWWAcla	2,47	2,54
LWWAPLS comp1	2,33	2,38
LWWAPLS comp2	2,35	2,37
LWWAPLS comp3	2,44	2,45
LWWAPLS comp4	2,6	2,57
LWWAPLS comp5	2,76	2,68

Cross-validated model perfomance for the Tjan estimation (method "Leave one out")



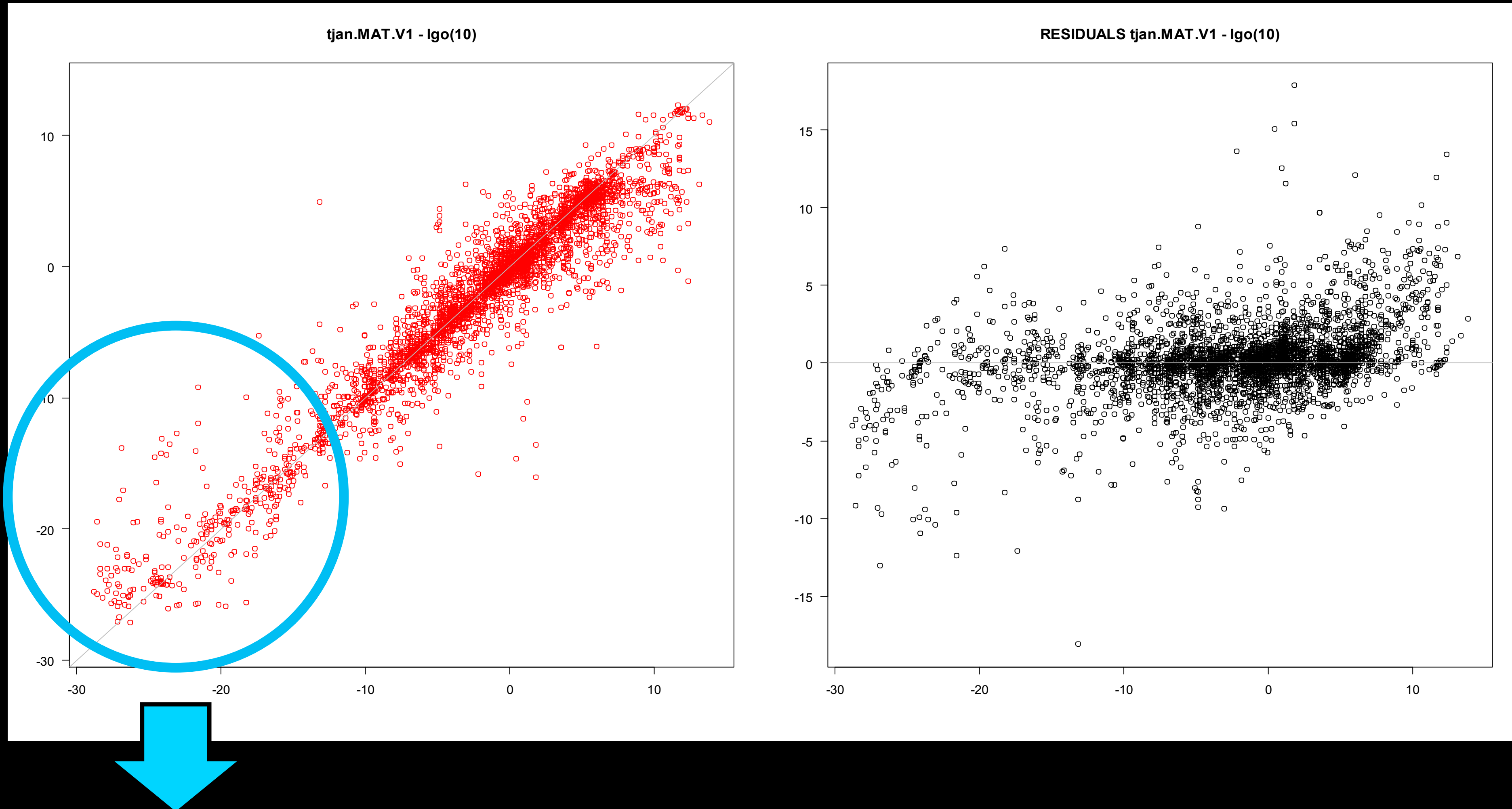
wMAT

Model	RMSE	RMSEP
MAT k2	1,94	1,97
MAT k3	1,89	1,96
MAT k4	1,91	1,96
MAT k5	1,92	1,98
wMAT k2	1,91	1,94
wMAT k3	1,85	1,91
wMAT k4	1,85	1,9
wMAT k5	1,85	1,91
LWWAinv	2,01	2,06
LWWAcla	2,27	2,34
LWWAPLS comp1	2,04	2,08
LWWAPLS comp2	2,09	2,07
LWWAPLS comp3	2,26	2,25
LWWAPLS comp4	2,44	2,41
LWWAPLS comp5	2,57	2,57

LWWA

LWWA-PLS

Cross-validated model perfomance for the Tjul estimation (method “Leave one out”)



The model is weak in reconstructing the cold extremes along the gradient, resulting in T overesimation
Explanation: overestimation due to long – distance transport of pollen from the lowlands up to higher altitudes

Cross-validated model perfomance for the Tjan estimation, wMAT method (method "Leave one out")