

Introduction

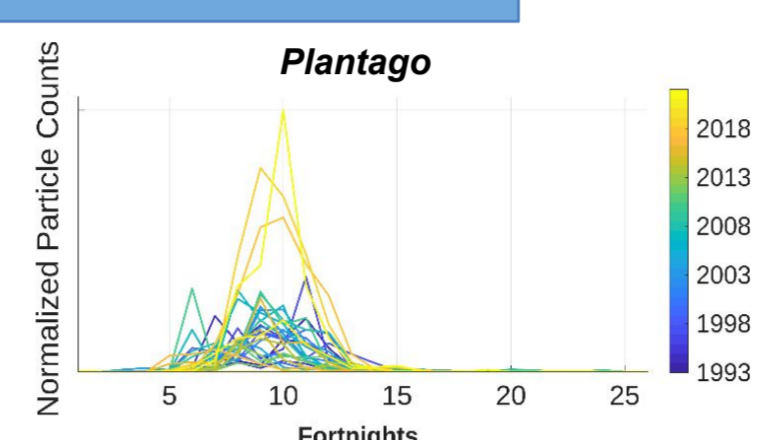
- Observational **time series** often exhibit cyclic behavior at multiple scales.
- This work introduces a unified analysis pipeline that adapts **ANOVA Simultaneous Component Analysis (ASCA)**, traditionally applied to experimental data, for **observational frameworks**.
- This pipeline provides both statistical **inference** and PCA-driven **visualizations** for observational time series data.



Methodology

Cyclostationary time series

- Data approximately repeat in **cycles** across multiple **scales**.



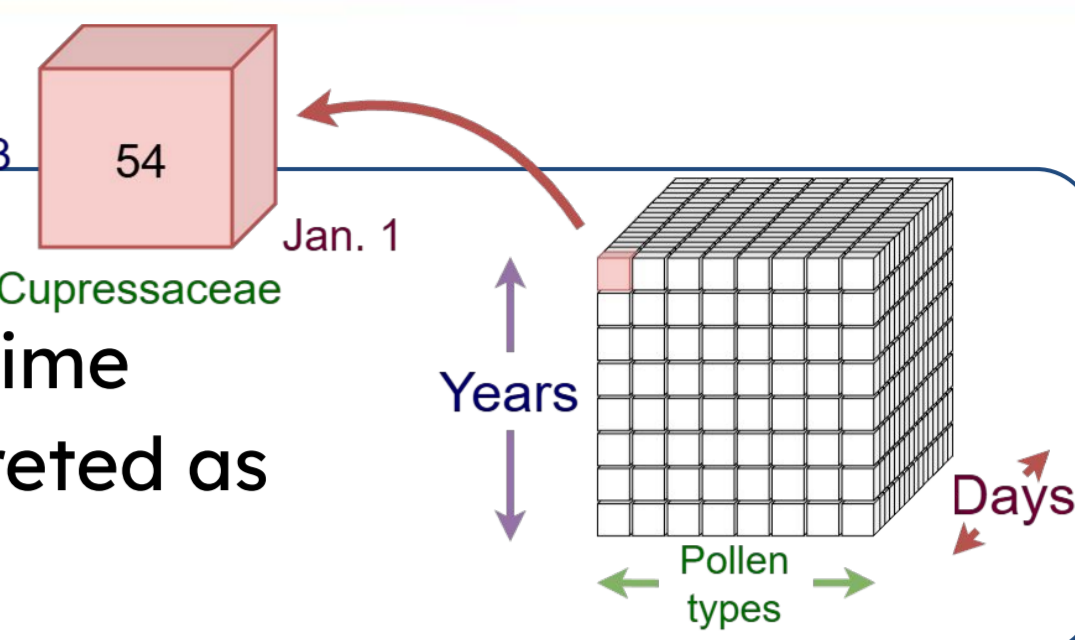
Unfolding

Year	Fortnight	Cupressaceae	...	Olea
1993	Fortnight 1	3.4	...	
1993	Fortnight 26		...	
1994	Fortnight 1	20.2	...	
...
2022	Fortnight 26	5.6	...	

- Tensor modes are unfolded to **rows** and **columns**.
- Each unfolding results in a different ASCA model.

Tensor

- Cyclostationary time scales are interpreted as **tensor modes**.



ASCA

1. Factorization of the data in factors and interactions.

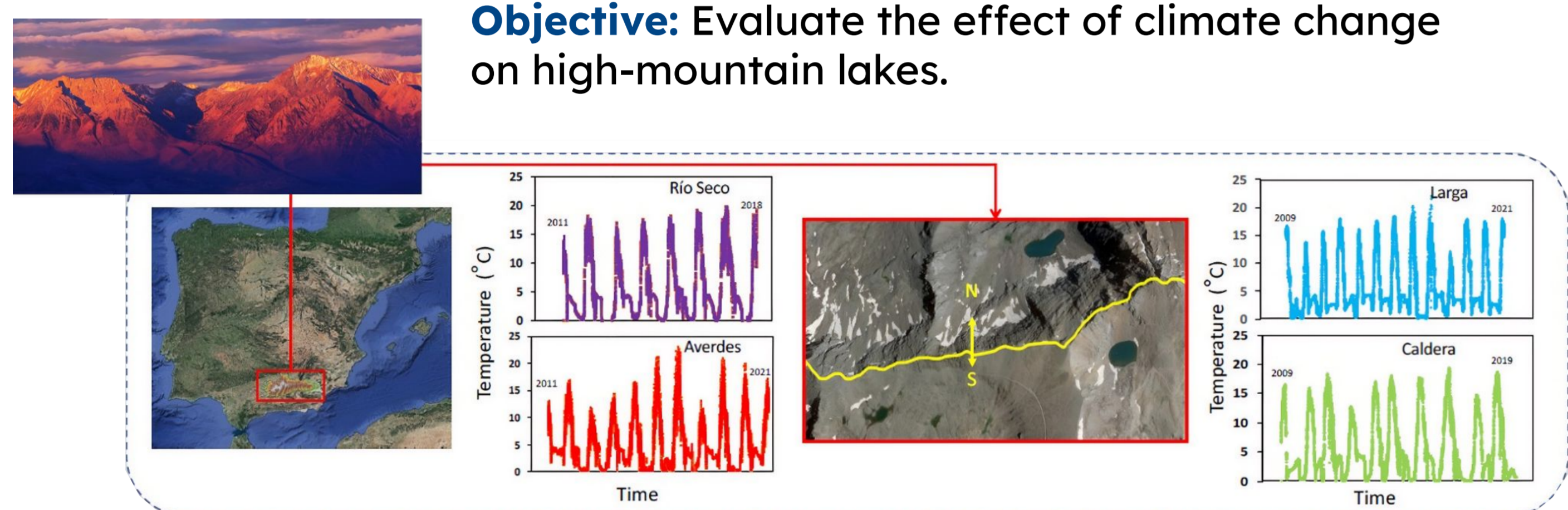
2. Significance testing for each factor and interaction.

3. Visualization to interpret sample-variable relationships.

Climate change observatory

Data: Water temperature measurements from seven sensors in four high-mountain lakes in Sierra Nevada (Spain), from 2009 to 2021.

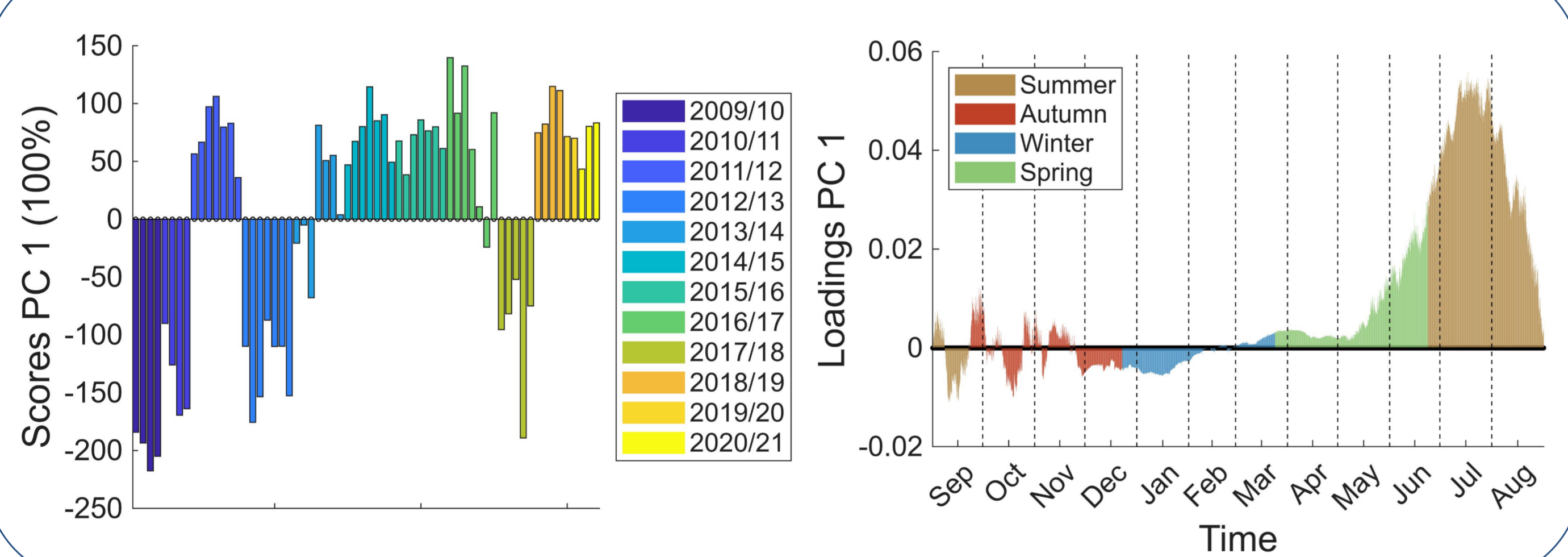
Objective: Evaluate the effect of climate change on high-mountain lakes.



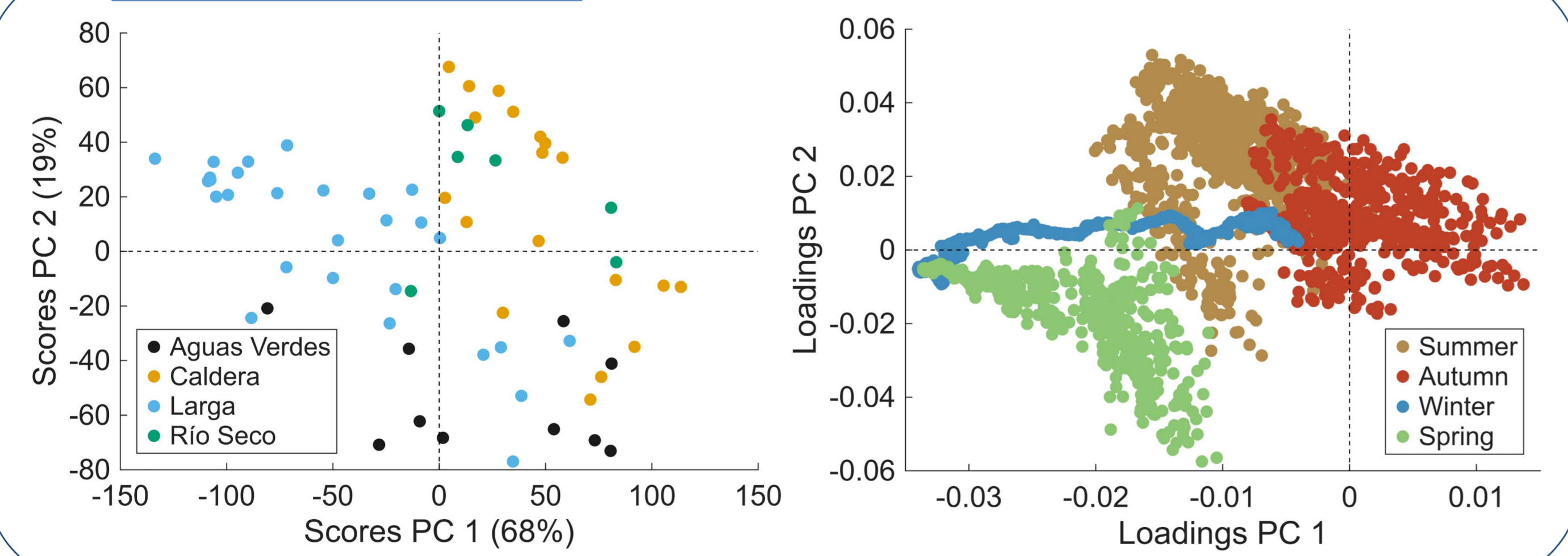
Results:

Source	Sum of Squares	Sum of Squares (%)	Degrees of Freedom	Mean Squares	F-statistic	p-value
Year (ordinal)	1.81×10^5	14.7	1	18.1×10^4	10.97	< 0.001
Sensor	2.28×10^5	18.5	6	3.80×10^4	2.30	0.016
Year × Sensor	7.24×10^4	5.9	6	1.21×10^4	0.73	0.882
Residuals	8.26×10^5	67.0	50	1.65×10^4	—	—
Total	1.23×10^6	106.0	63	1.96×10^4	—	—

Factor 'Year'



Factor 'Sensor'

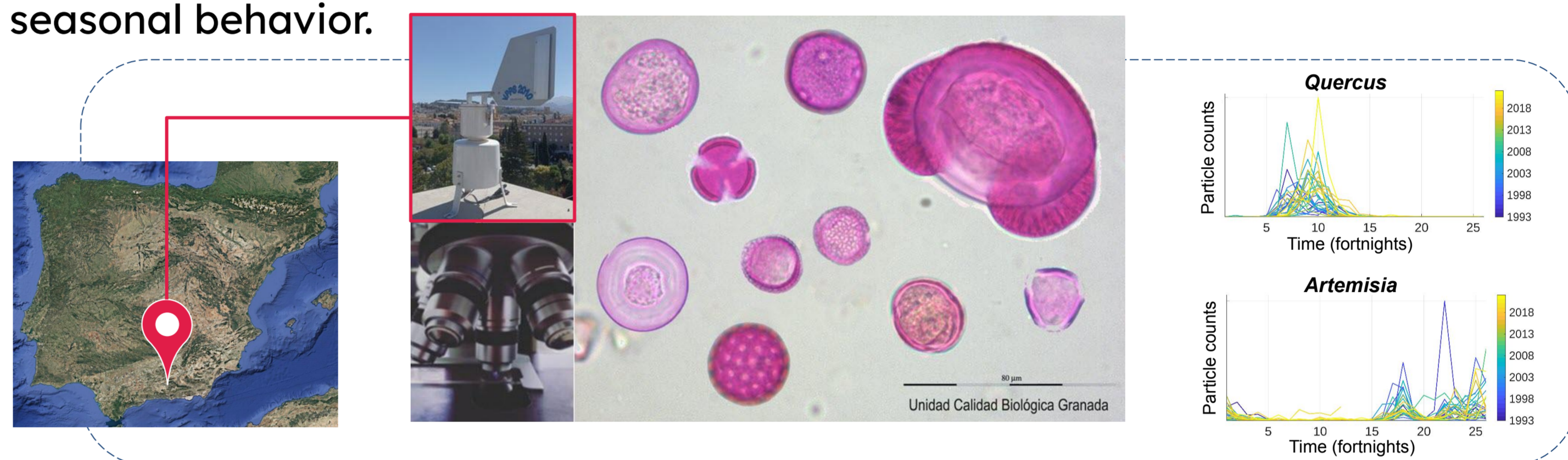


- Summer temperatures rise while the rest of the year remains stable.
- Geographical location—northern slope (Larga) vs. southern slope (the other three)—affects seasonal temperature patterns, but heating is consistent across all lakes.

Understanding allergies

Data: Daily measurements of airborne pollen concentration for 44 pollen types collected over 30 years (1993 – 2022) in Granada (Spain).

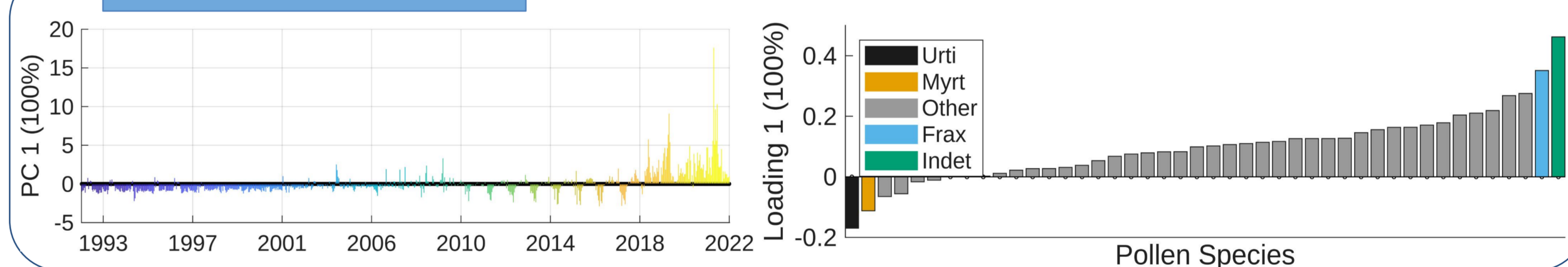
Objective: Determine changes in pollen concentrations over the years and shifts in seasonal behavior.



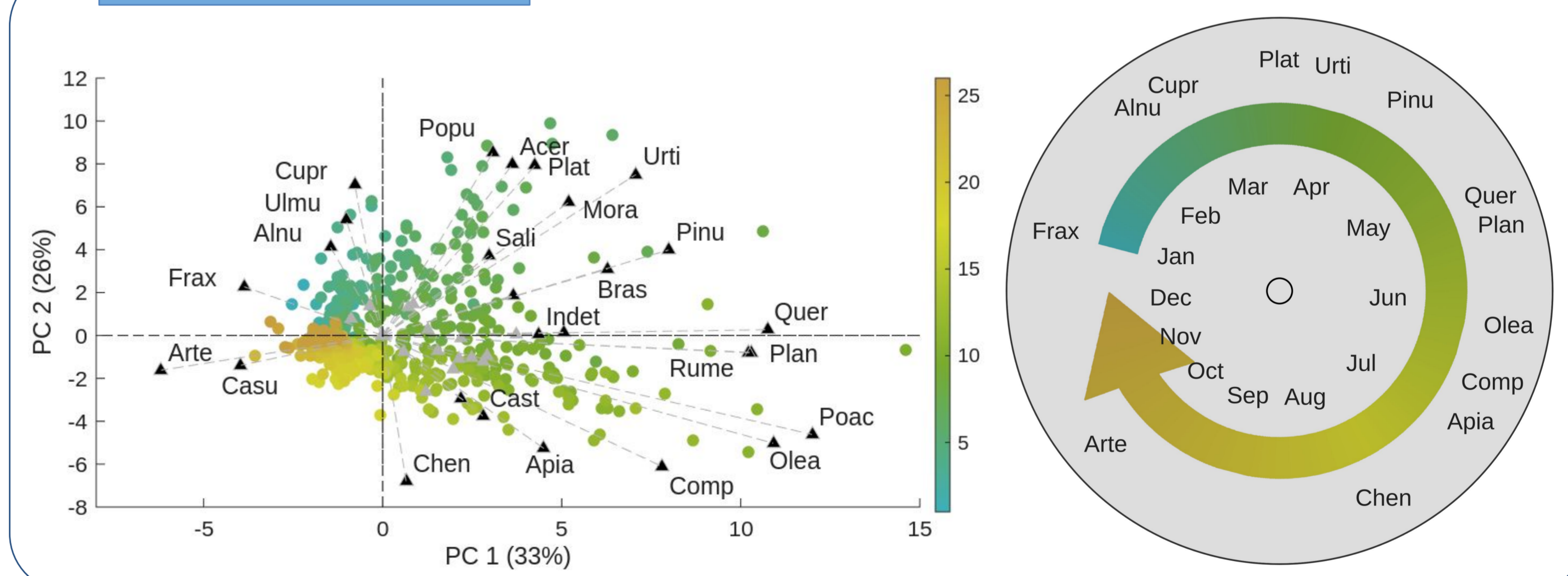
Results:

Source	Sum of Squares	Sum of Squares (%)	Degrees of Freedom	Mean Squares	F-statistic	p-value
Year (ordinal)	3.98×10^2	1.3	1	398.5	12.94	< 0.001
Fortnight (14-day period)	7.64×10^3	24.2	25	305.6	9.93	< 0.001
Fortnight × Year	1.94×10^3	6.1	25	77.6	2.52	< 0.001
Residuals	2.16×10^4	68.4	702	30.8	—	—
Total	3.16×10^4	100.0	753	42.0	—	—

Factor 'Year'



Factor 'Fortnight'



- Major concentrations increase from 2018 to 2022, especially *Fraxinus* and “Indeterminate” pollen.
- The “Indeterminate” spike revealed recording errors, prompting a revision of the data recording process.
- ASCA plots capture the seasonal nature of pollen types over the course of the year.

References

- Smilde, A. K. et al. (2005). ANOVA-simultaneous component analysis (ASCA): a new tool for analyzing designed metabolomics data. *Bioinformatics*, 21, 3043–3048. doi:10.1093/bioinformatics/bti476.
- Vallejo-España, D. et al. (2026). Modeling cyclostationarity in time series using ASCA. Submitted to *Chemometrics and Intelligent Laboratory Systems*. doi:10.48550/arXiv.2603.05065.



Reference link

Acknowledgements

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