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# Biogeographical regions and their flowering phenological patterns across Europe

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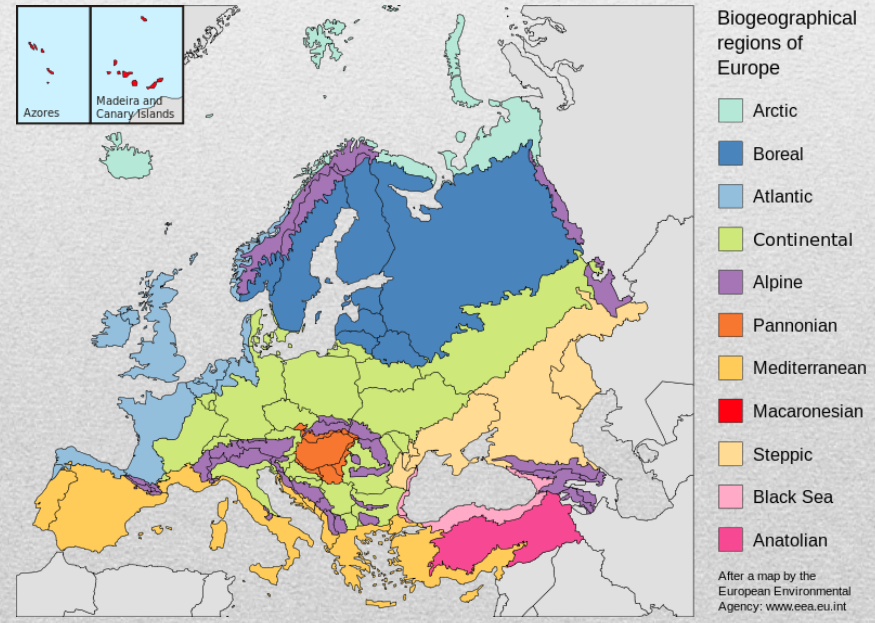
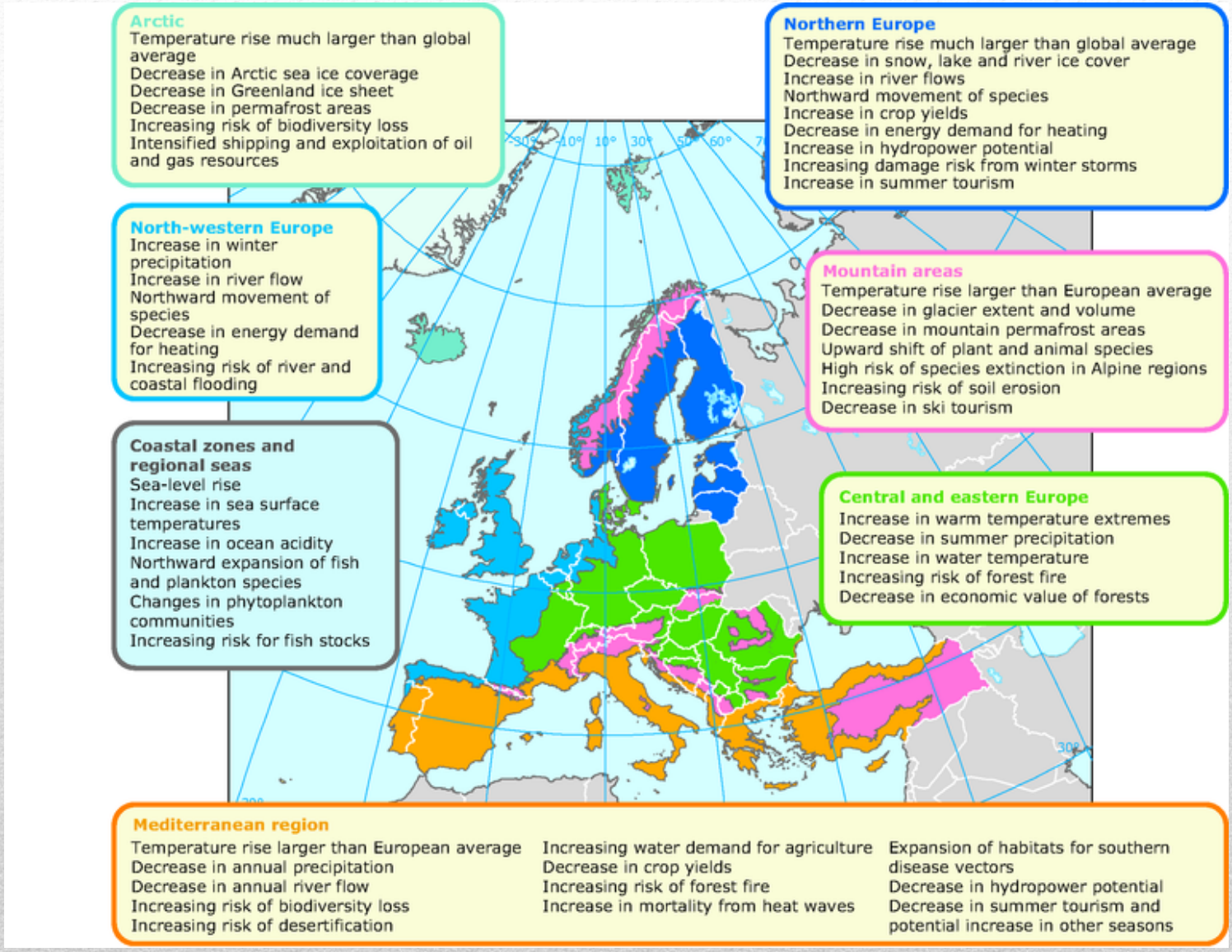
# Introduction

- climate change is evident across Europe causing a wide range of impacts on the environment (EEA, 2012)
- from the Northern (Schwartz et al. 2006) to the Southern Hemisphere (Chambers et al. 2013) shifts in timing of particular stages of plant development observed
- these responses are species- and phenophase- specific, geographical differences in their main drivers

- Biogeographical regions "are useful geographical reference units for describing habitat types and species which live under similar conditions in different countries" (Roekaerts, 2002).






**Observed and projected climate change and impacts for biogeographical regions of Europe (EEA, 2012)**

- to compare various biogeographical regions, and test whether the areas experienced advancement in timing of flowering
- to evaluate the possible factors that influence phenological shifts
- to discover phenological patterns along various latitudes and periods

# Motivation

Szabo et al. 2015, GCB in prep.

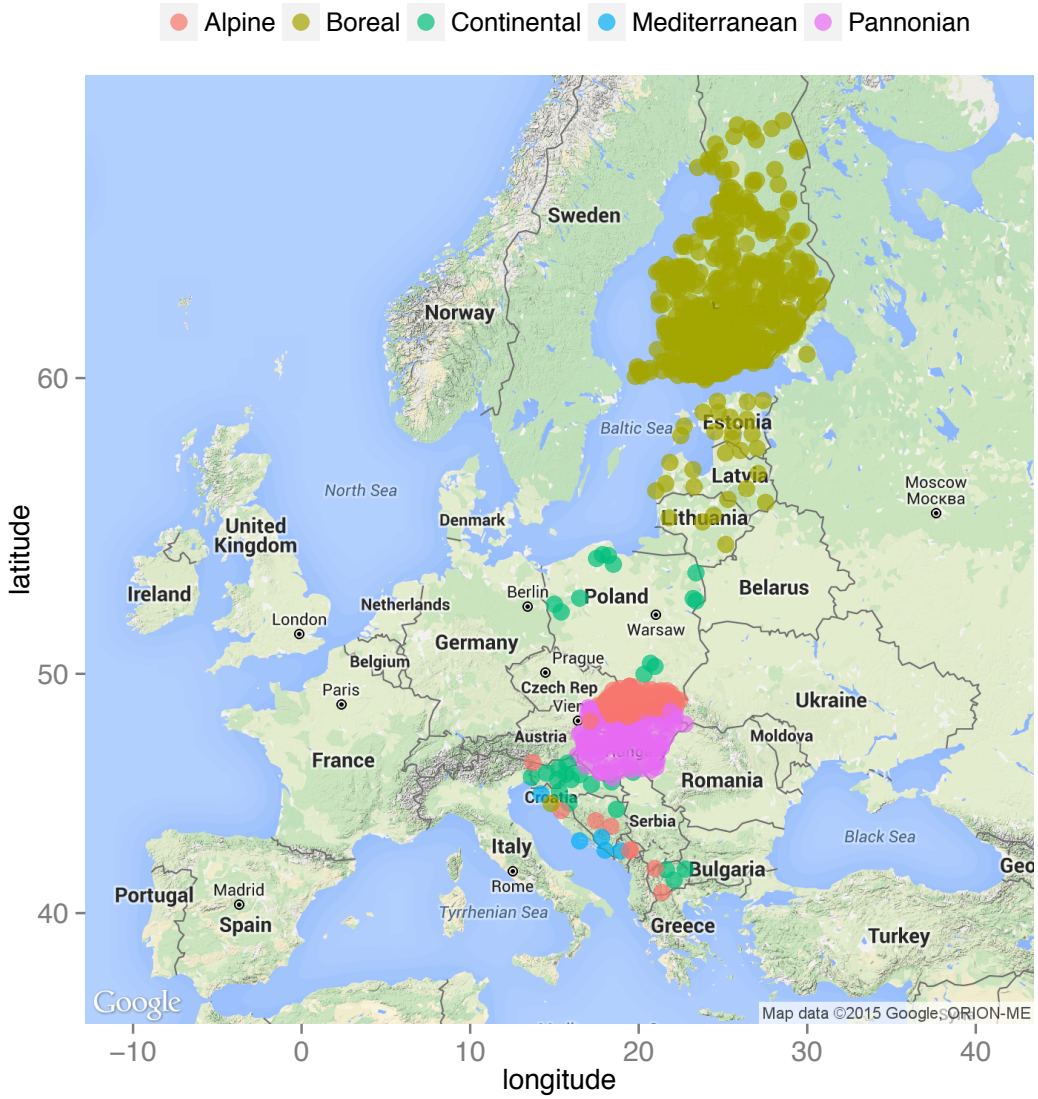
# Materials and Methods: Phenological datasets

- 6 wild plant species

(*Convallaria majalis, Sambucus nigra, Syringa vulgaris, Taraxacum officinale, Tilia cordata, Robinia pseudoacacia*)

- flowering phenological observations from north-south transect in Central-Eastern Europe
- 12 country (Finland, Estonia, Latvia, Lithuania, Poland, Slovakia, Hungary, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Macedonia)
- metadata: latitude, longitude, altitude
- 5 biogeographical region (Boreal, Continental, Alpine, Pannonian, Mediterranean) – data from the European Environment Agency (EEA)
- 40 year: 1970 - 2010

Longitude range: 13.6 - 32.1 degree




Latitude range: 40.9 - 67.9 degree

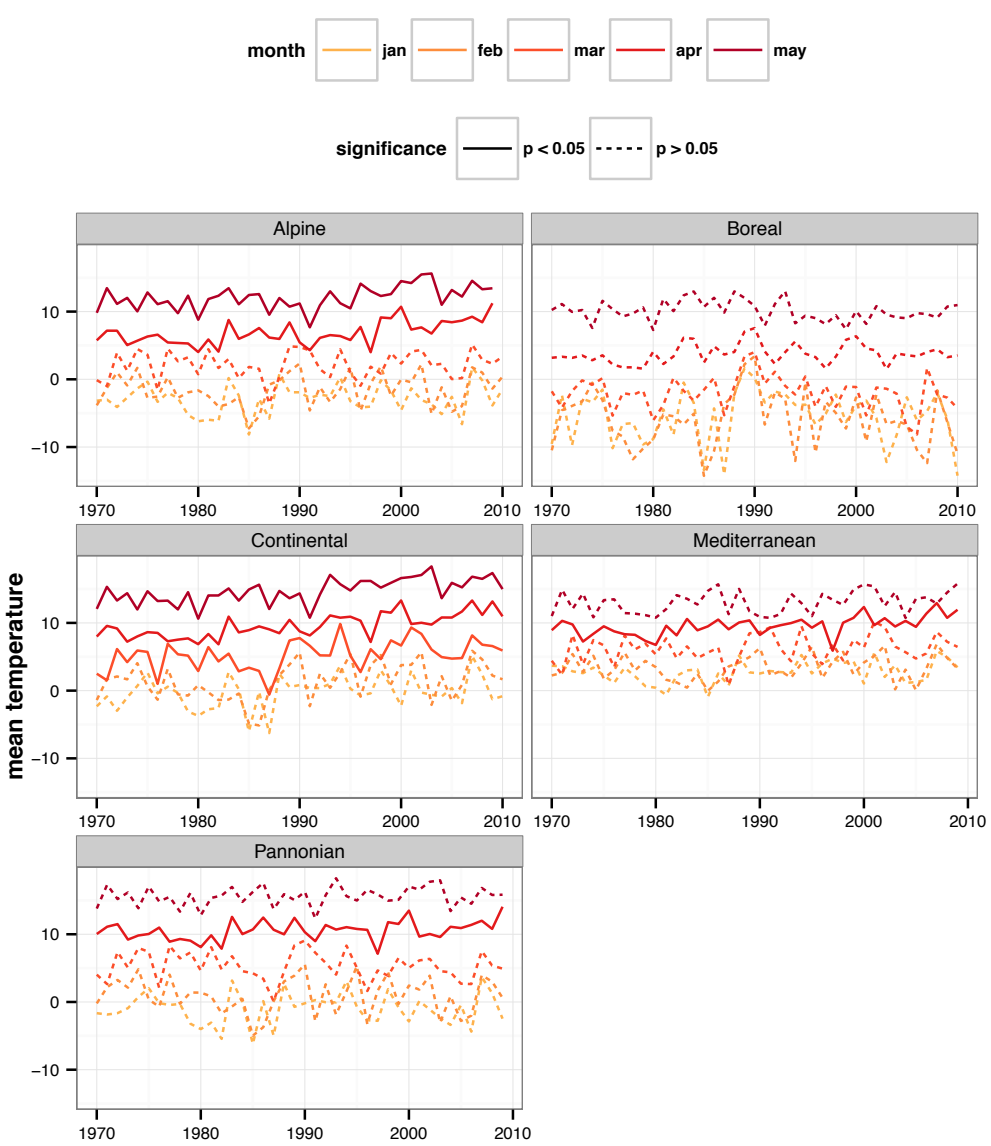
# Biogeographical regions

# Materials and Methods: Climatological datasets

- daily data of air temperature (mean, minimum, maximum), precipitation and monthly indices of the North Atlantic Oscillation (NAO)
- data source: E-OBS regular gridded (0.25 degree) datasets developed by the ENSEMBLES EU-FP6 project and Climate Research Unit (CRU) of the University of East Anglia
- Further data: quartiles at 0.25, 0.5 (median), 0.75 level; skewness of climate data series were also determined
- 40 year: 1970 - 2010

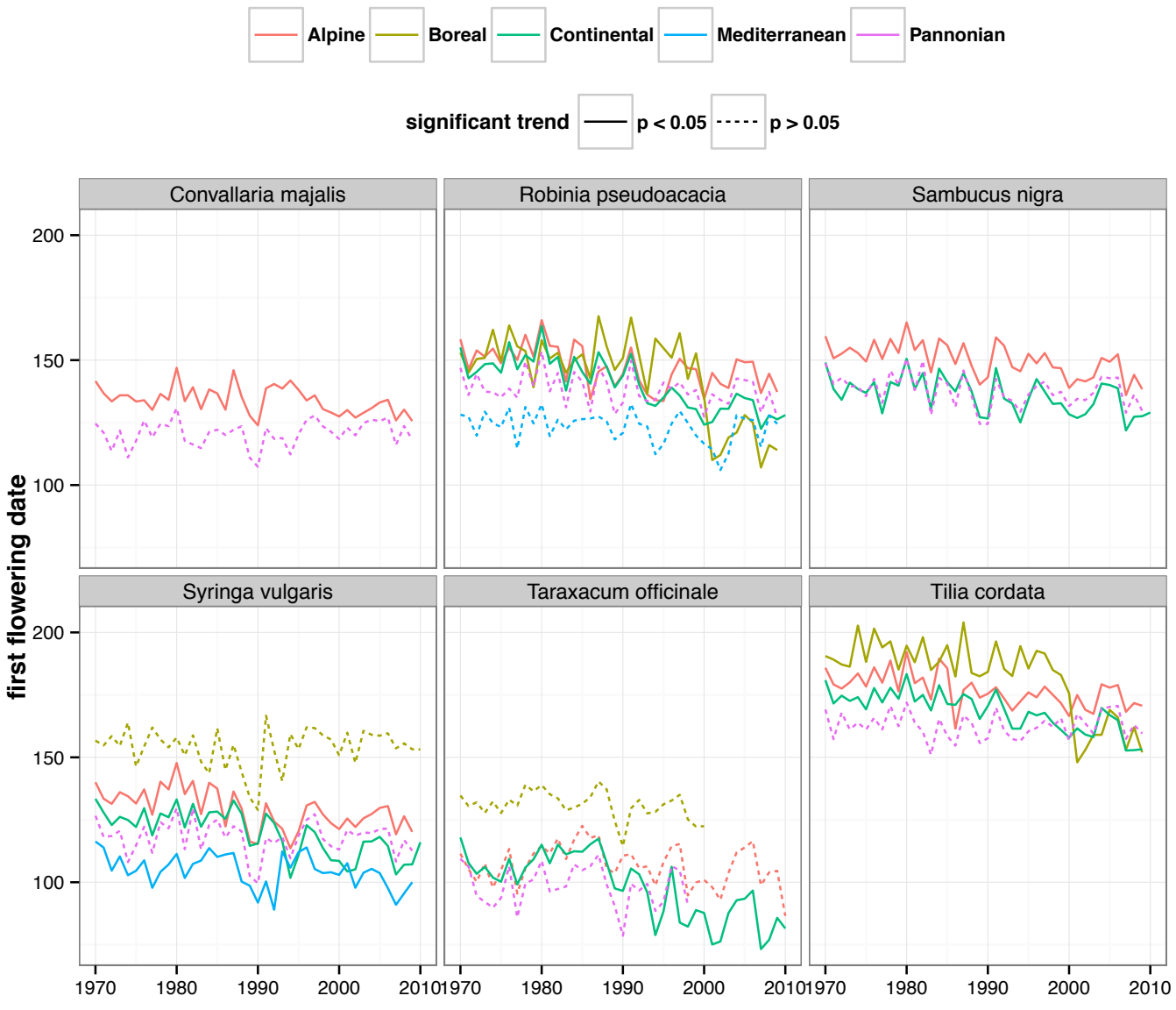
# Materials and Methods: Statistics

- Two-way linear mixed models – pheno package (*pheno* R package - Schaber&Badeck, 2002)
- all analyses were carried out on 30 homogenized phenological time series for the 6 species over the 5 biogeographical regions
- outliers -> robust methods (*robustbase* R package – Rousseeuw&Croux, 2015)
- Robust linear regressions
- Heatmap for the visualization of the regression coefficients & hierarchical clustering based on them

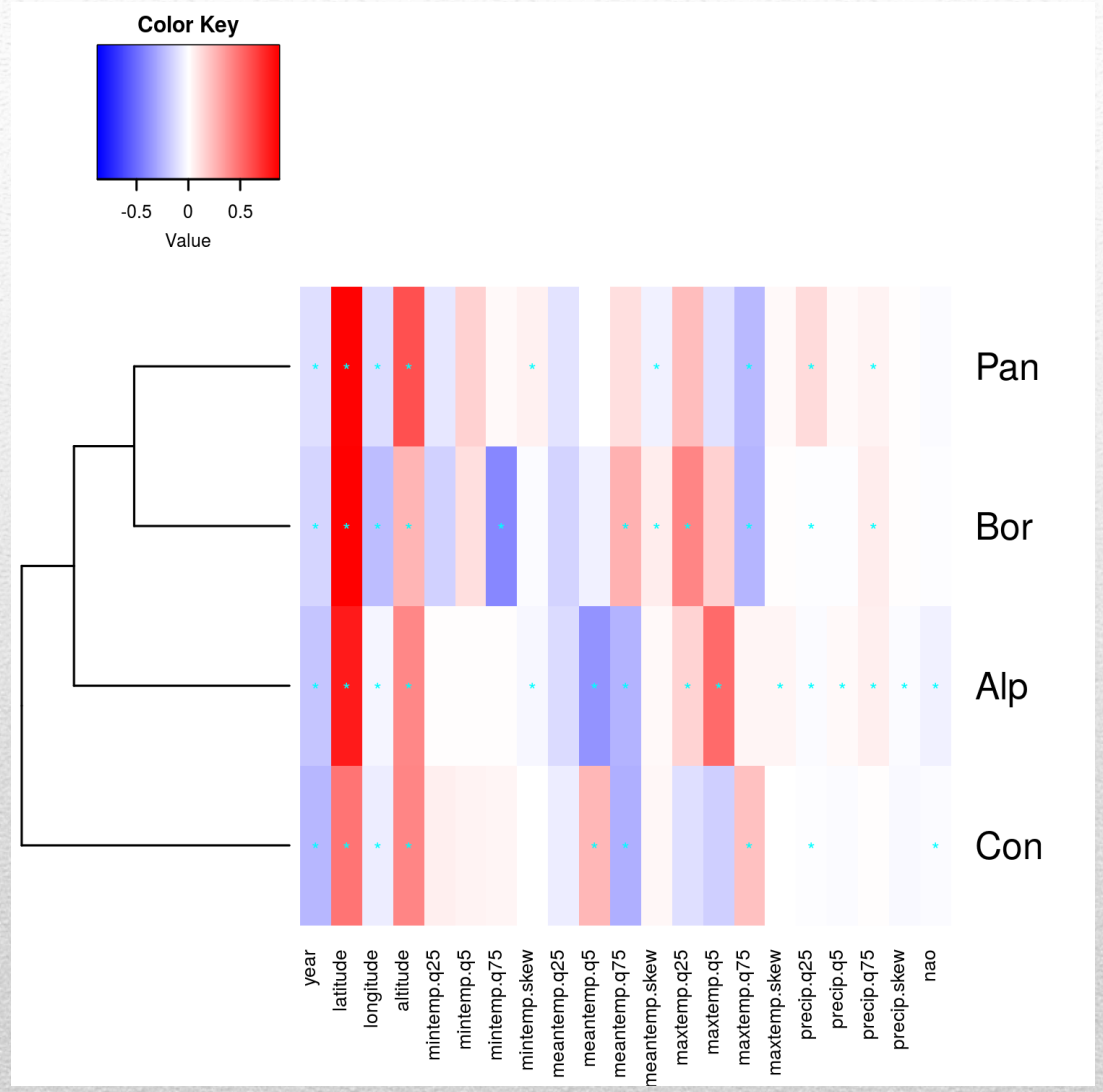



# Results: Annual variation and trends of mean temperature (1970-2010)

Szabo et al. 2015, GCB in prep.



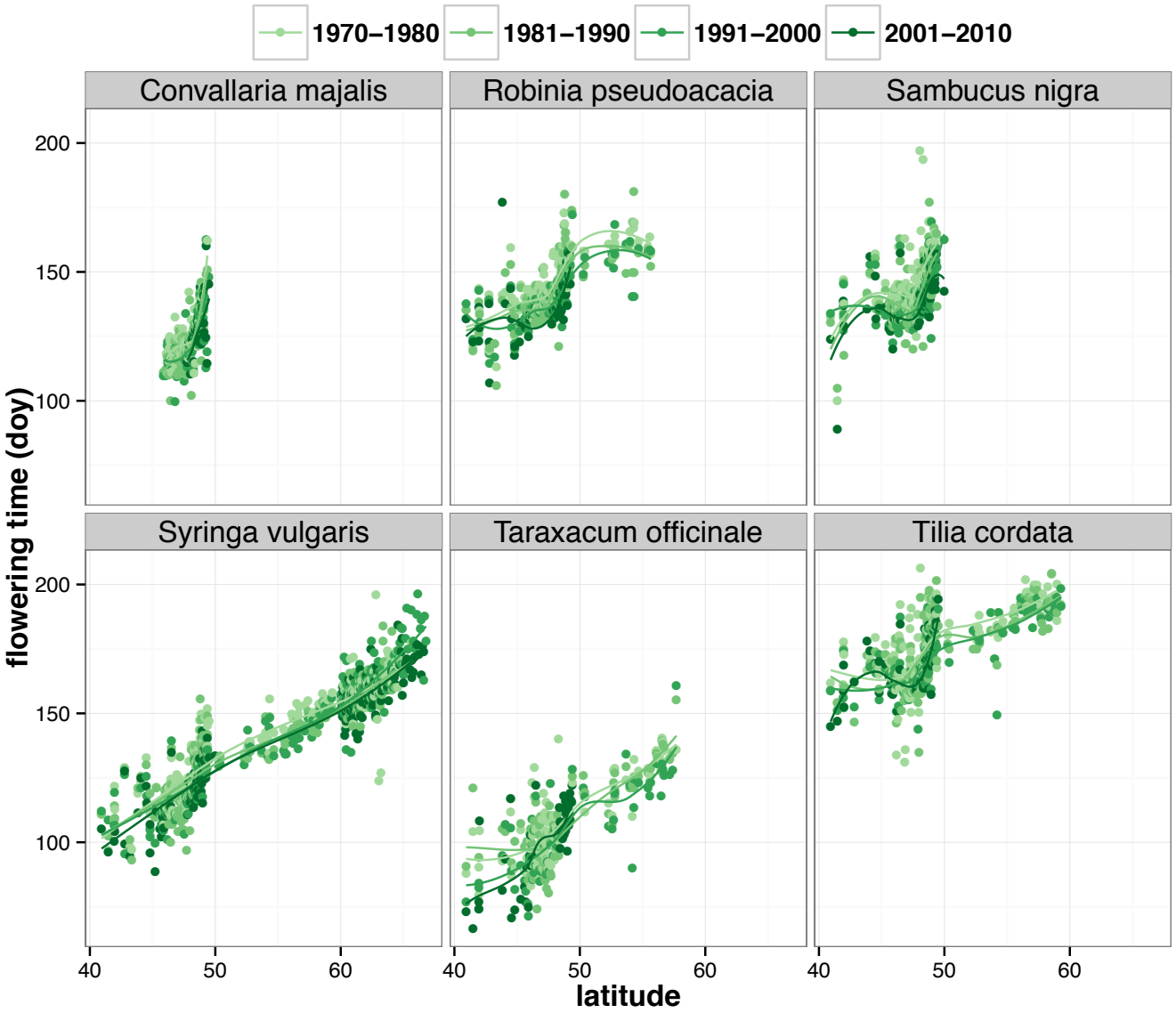

# Results: Inter-annual variation of the timing of flowering onset (1970-2010)




As an example:
*Tilia cordata*

Beta coefficients given for the most influential explanatory variables in different biogeographical zones. (Negative values (blue) indicates their negative effect on phenological response. Significant predictors indicated with dots.)

Szabo et al. 2015, GCB in prep.




## Results: Flowering onset dates along latitudes over decades (1970-2010)

# Flowering onset trends (days/year) in 1970-2010 across biogeographical regions of Europe

| | *Convallaria* | *Robinia* | *Sambucus* | *Syringa* | *Taraxacum* | *Tilia* |
|---|---|---|---|---|---|---|
| Alpine | **- 0.26** | **- 0.32** | **- 0.33** | **- 0.23** | 0.01 | **- 0.24** |
| Boreal | -0.07 | **- 0.52** | - | - | - 0.17 | **- 0.19** |
| Continental | - | **- 0.53** | **- 0.28** | **- 0.31** | **- 0.40** | **- 0.35** |
| Mediterranean | - | - 0.12 | - 0.08 | **- 0.14** | - 0.35 | - 0.17 |
| Pannonian | 0.06 | - 0.12 | - 0.11 | - 0.03 | - 0.05 | - 0.03 |

Empty cells: non-studied cases;
negative bold values: significant advancing trends

- significant advancement of mean flowering onsets in the Alpine and Continental region
- strongest advancement were given by *Robinia p., Tilia c.*
- species, living in northern or higher latitudes were characterised by later dates of flowering onset
- the flowering started earlier at recent decades (1991-2010)
- significant negative effect of NAO, while positive influence from mean temperature previous to flowering
- the effect of precipitation sum are sporadic

# Conclusion


# Thanks for your attention!