



Results of Phenoplant

Phenological monitoring of alpine flora

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Phenoplant Objectives

- **Develop common sampling protocol** used by a large number of actors
- Identify and select **indicators of global change** from alpine flora phenology
- Build a **network of observation** sites on phenology
- **Understand effect** of years, temperature and other environmental factors on flora development.

Meteo network (Cf.poster)

- Link between observations and global change
- Network of meteorological station near observation sites of flora and fauna
- Station **measure temperatures and snow duration** all along years
- 3 Years of implantations to develop the network in the Italian Alps

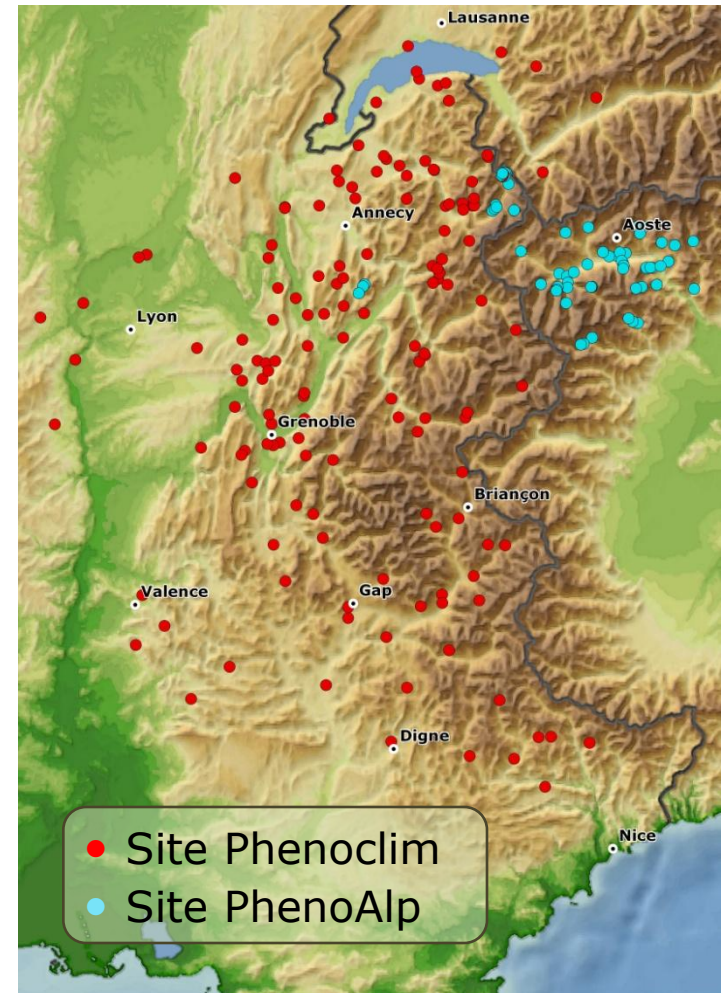


Phenoplant in forest : Phenoclim

- **63 sites** developed
- Mobilize Italian professionals in protected area (involvement of Aosta Valley forest ranger)
- Implementation of **altitudinal Transects**

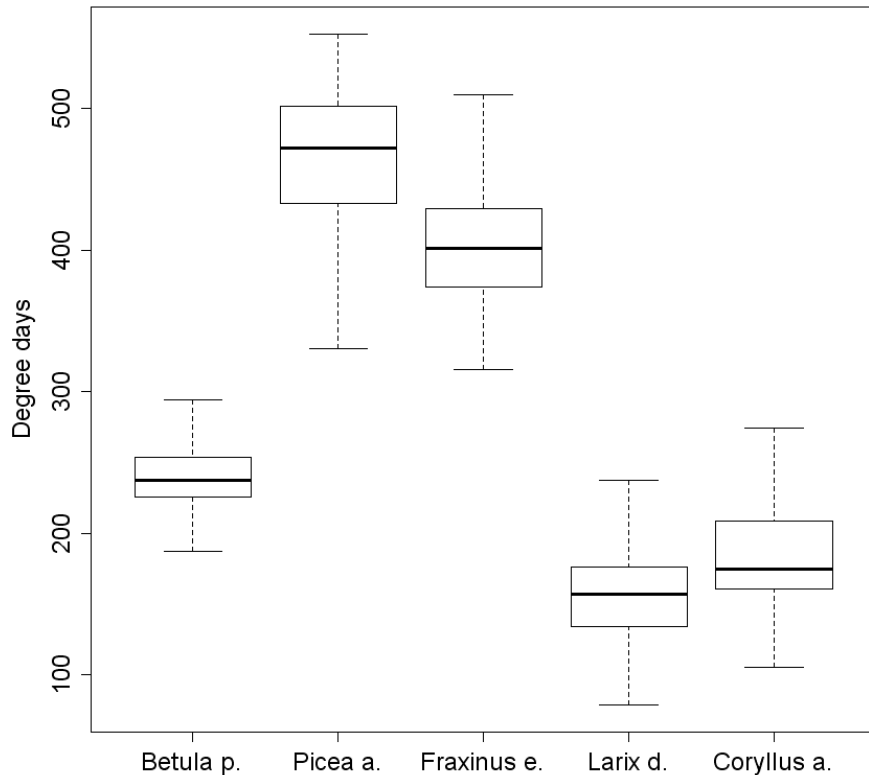
Protocol

- 1 site
 - 3 species among a list of 10
 - 3 individuals per species



Phenoclim results on Budburst from 2006 to 2011

- Tree species need different level of temperature accumulation to budburst
- Cumulated degrees needed to budburst vary among years



Year	Degree days
2006	290
2007	307
2008	287
2009	294
2010	299
2011	254

+ 19 degree days

- 35 degree days

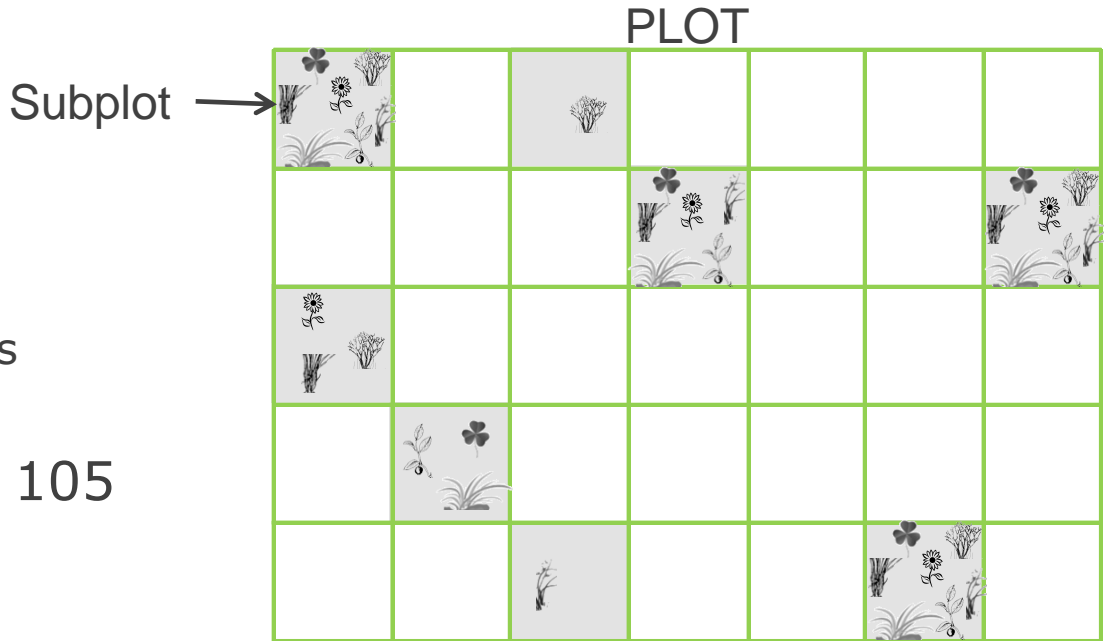
Fixed Factor	R ²
Species	0.74
Year	0.10
Altitude	0.4








Random factor	% of variance
Site	0.25
Individual	0.14
Residuals	0.62

Phenoplant on alpine grassland

Protocol

- 6 sites
 - 3 plots
 - 5 subplots
 - 7 growth forms
- Weekly monitoring of 105 individuals
 - Reproductive phase
 - Length of 5 leaves
- 12 Quadras (50 x 50 cm)
 - Picture of corner
 - 5 height of vegetation
 - Greenness estimation



	Code	Growth forms	Species
	DS	Deciduous shrubs	<i>Vaccinium myrtillus</i>
	ES	Evergreen shrubs	<i>Rhododendron sp.</i>
	FO	Forbs	<i>Arnica montana</i>
	LG	Leguminous	<i>Trifolium sp.</i>
	GP	Grazed Poaceae	<i>Agrostis capillaris</i>
	NG	Non grazed Poaceae	<i>Nardus stricta</i>
	SG	Sedges	<i>Carex sempervirens</i>

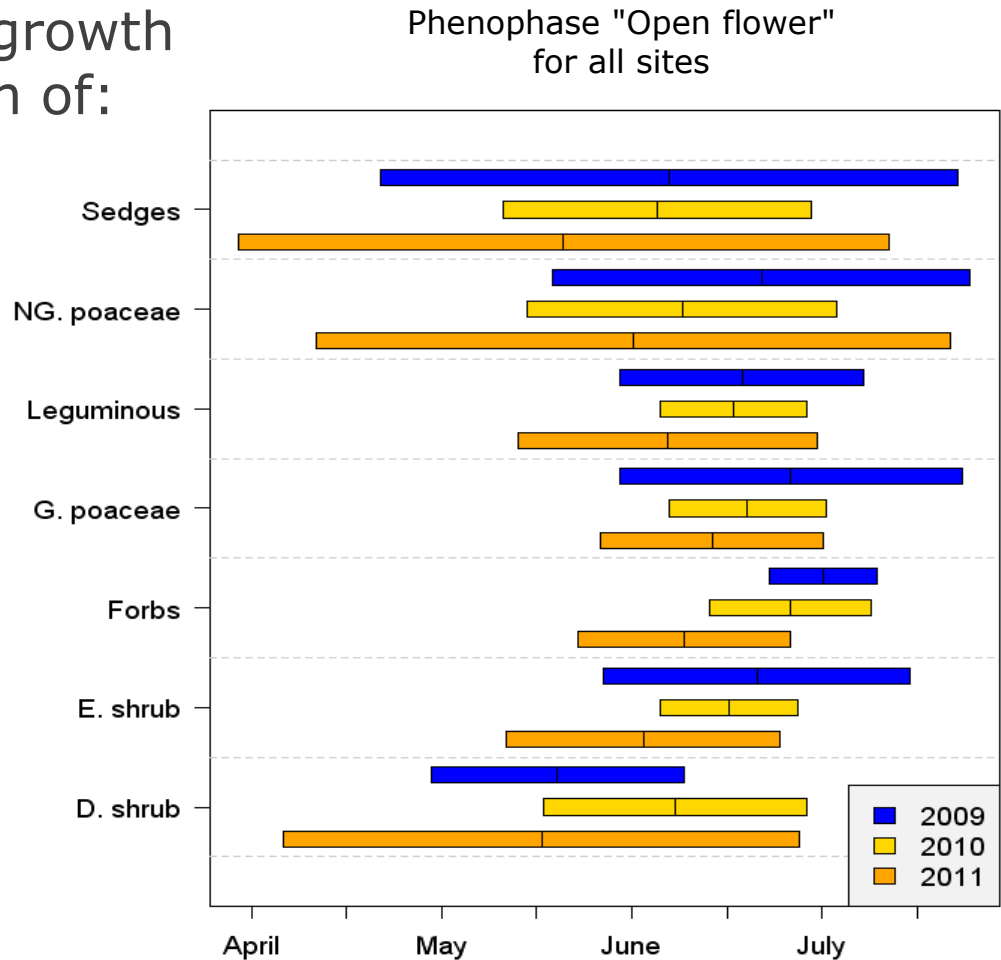
Descriptive models of phenology

Variability is explained by various factors :

- Sites in Phenopiant analyses **integrate environmental parameters** (exposure, pedology, altitude, temperature etc.). It is the most informative factor ($\approx 41-42\%$)
 - Growth forms represent **main patterns of phenological development** of flora. These categories explain also a large part of variance . ($\approx 25-36\%$)
 - Year effect represent climatic factor and globe change in a longer term (temperature, snow, precipitation). **Inter-annual variation** have impact on the model ($\approx 23-27\%$)
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Reproductive Phenology

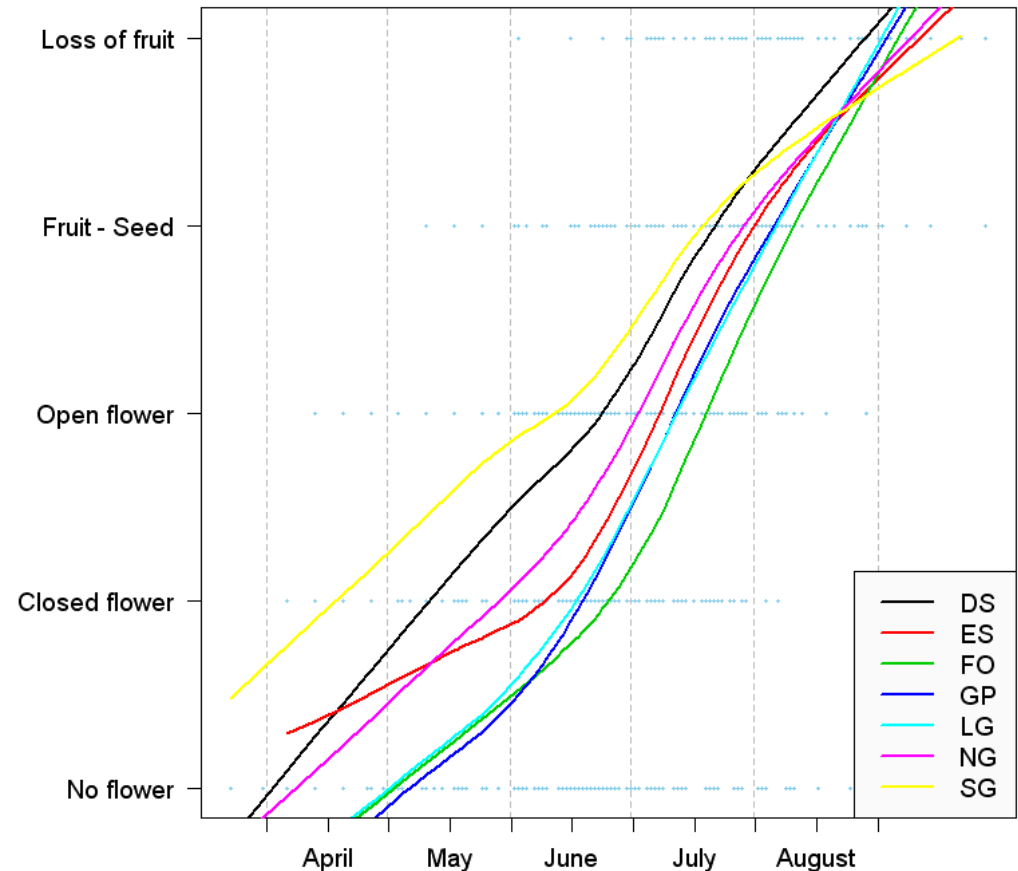
- Developments differences have been observed among growth forms and years in term of:
 - Average
 - variability



Reproductive Phenology

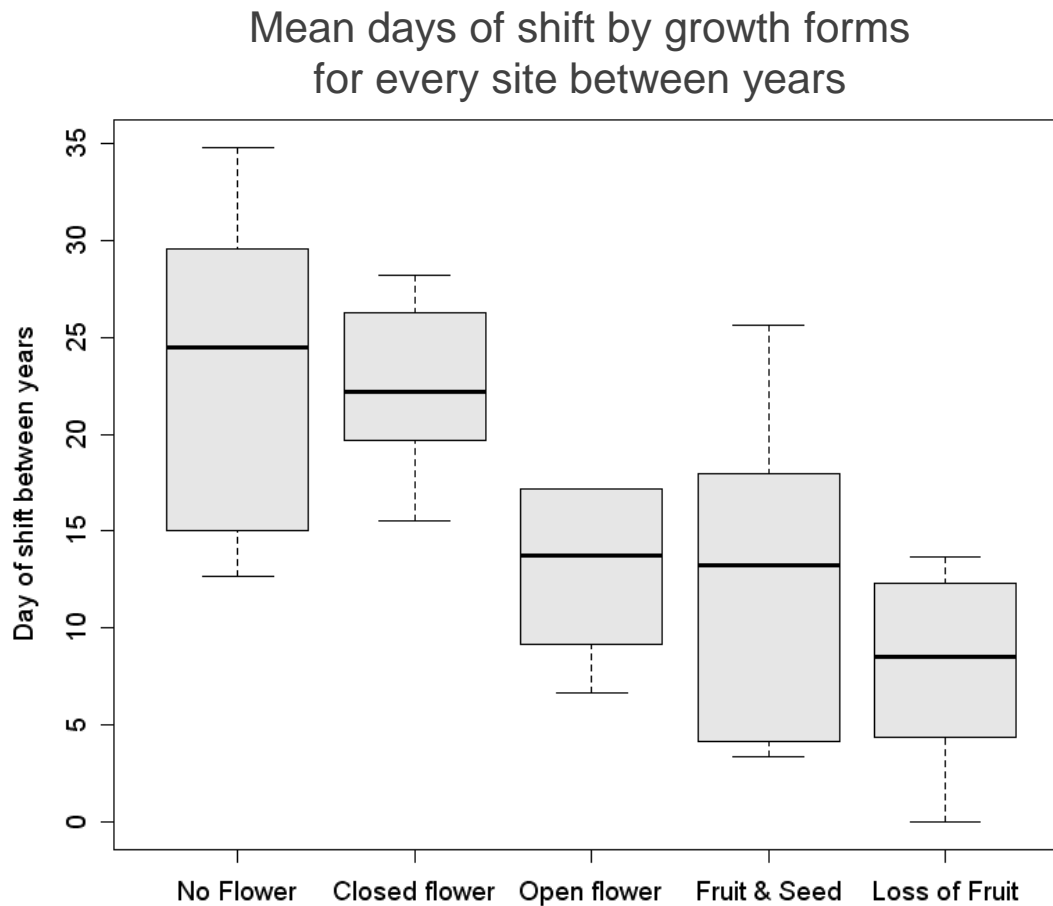
Growth forms dynamic

- Sedges and Deciduous shrubs are **early** categories
- Non grazed Poaceae and evergreen shrubs are **intermediate** species
- Grazed Poaceae, leguminous and forbs are the **latest**



Reproductive Phenology

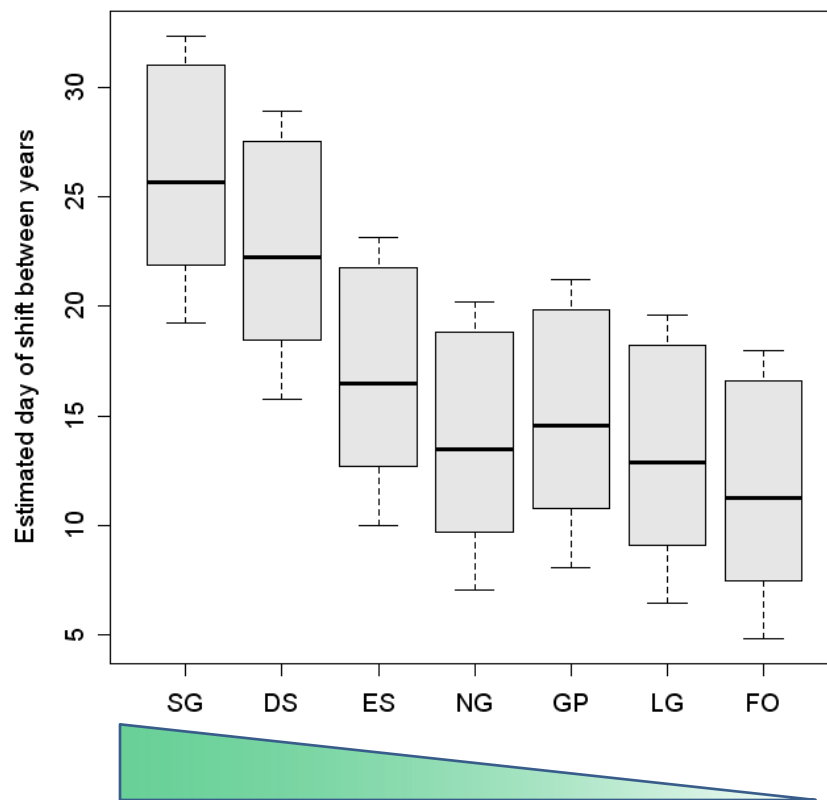
- Average shift of phenophases decrease for latest phenophases



Reproductive Phenology

- In addition earliest growth forms have a greater shift between years

Mean days of shift by growth forms for every site between years



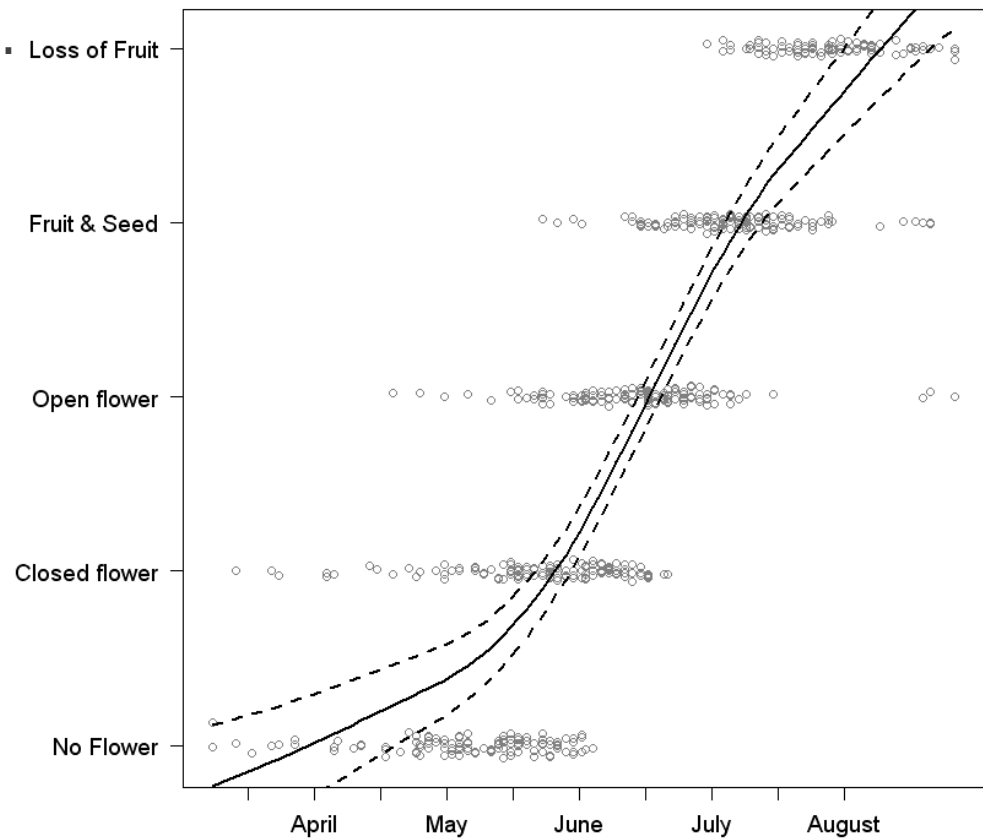
Early /late gradient of phenological development

Reproductive Phenology

- Phenophases "Closed flower", "Open flower" and "Fruit and Seed" are less variable among all sites and all years.
- No significant difference among growth forms.

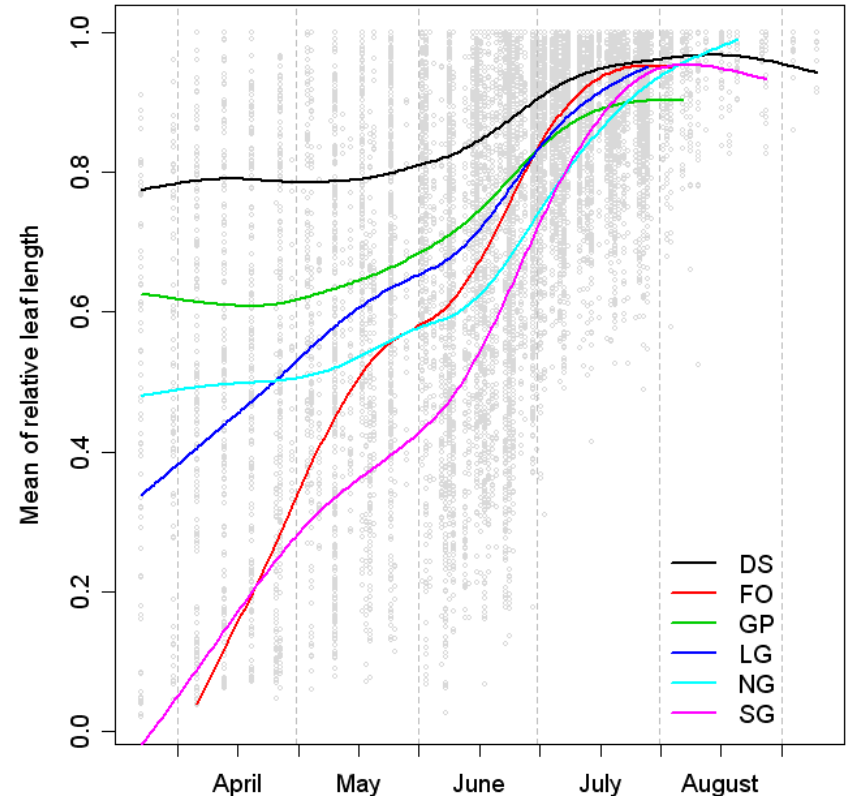
Phenophase	DS	ES	FO	GP	LG	NG	SG	Mean
No flower	0.12	0.11	0.09	0.09	0.09	0.09	0.12	0.10
Closed flower	0.09	0.07	0.08	0.09	0.08	0.07	0.09	0.08
Open flower	0.09	0.06	0.08	0.07	0.07	0.06	0.07	0.07
Fruit & Seed	0.08	0.07	0.11	0.08	0.10	0.07	0.08	0.08
Loss of fruit	0.15	0.10	0.15	0.11	0.13	0.09	0.11	0.12

Predicted mean of day for each phenophase



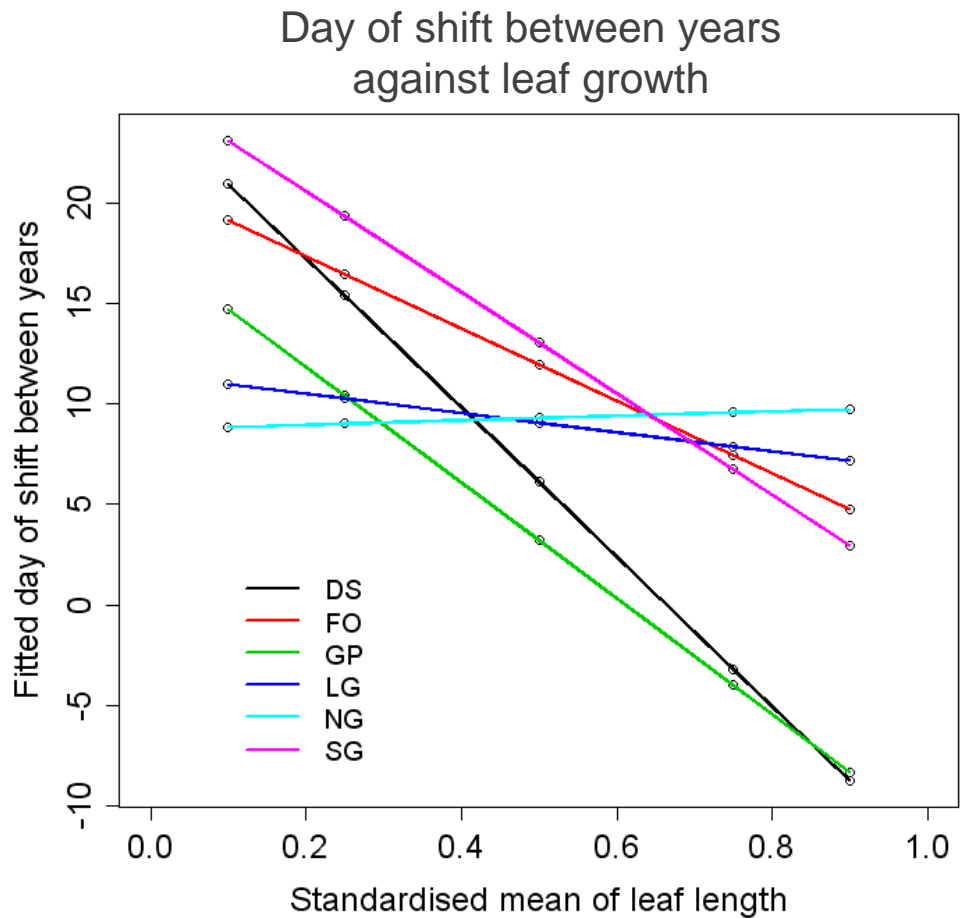
Vegetative Phenology

- Growth variability among growth forms
 - Shrubs (DS) stand out because they keep stems year to year
 - Grazed and Non grazed Poaceae have the same dynamic of development



Vegetative Phenology

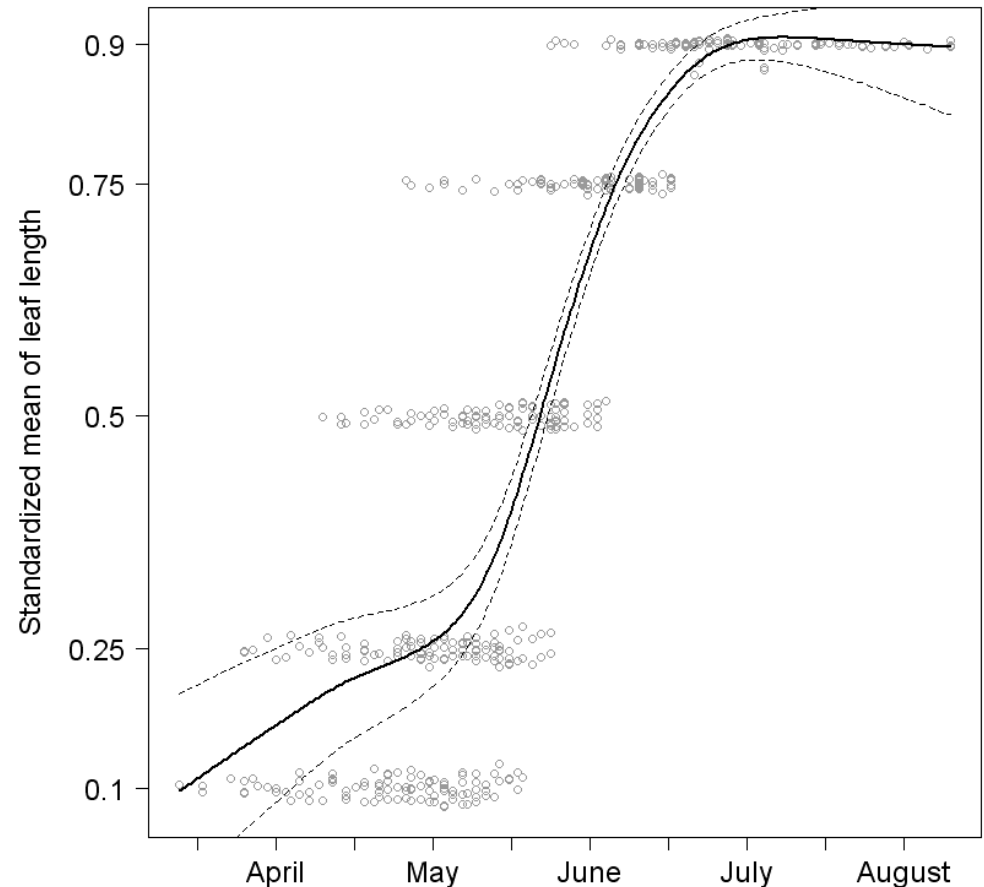
- Dynamic close from reproductive phenology : Earliest phenophases are more shifted between years
- Leaf length of Non grazed grasses and Leguminous does not seem to shift between years



Vegetative Phenology

- Measures are less variable in the middle of the growth season (June)
- Should be due to...
 - at the beginning of the season, greater uncertainty on measures on young leaves (small size)
 - at the end of the season greater uncertainty on measures on leaves (longest leaves are usually destroyed)
 - Natural variability

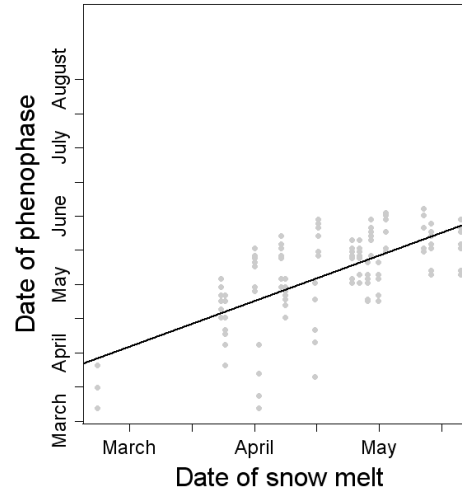
Predicted standardised mean of leaf length



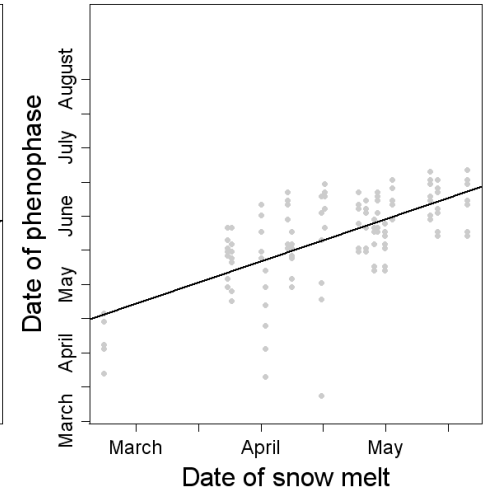
Snow melt and phenology

- Earliest **phenophases** and **leaf length** are more sensitive to the date of snow melt
- Growth form dynamics are not affected by snow melt

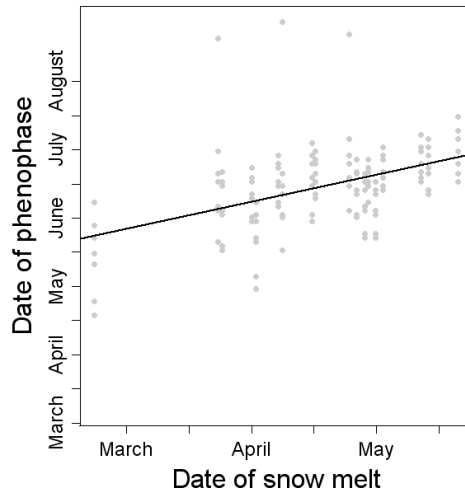
No Flower



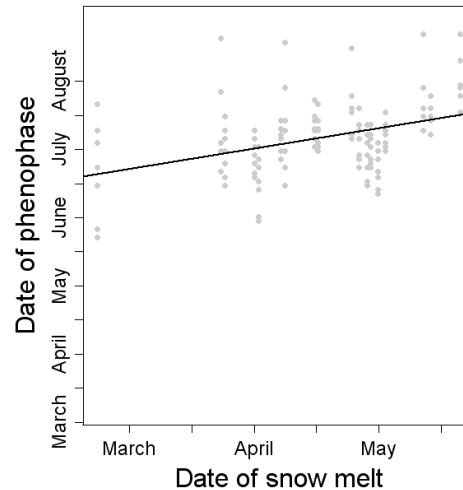
Closed flower



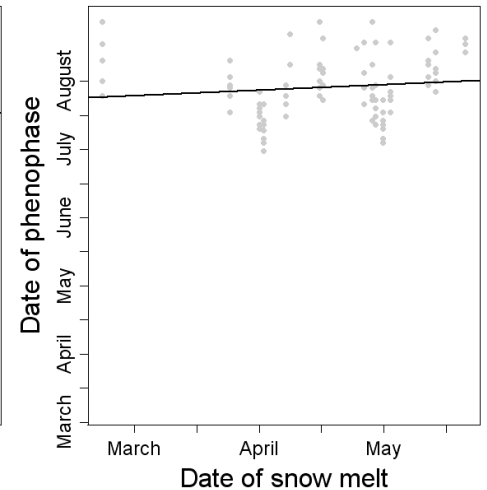
Open flower



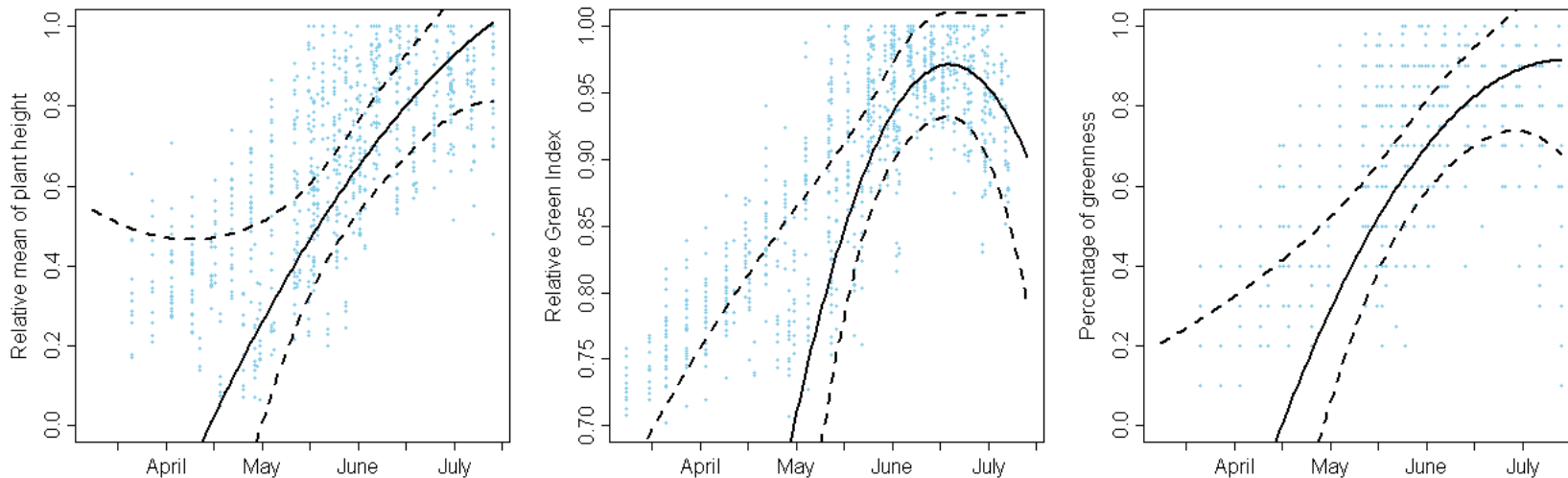
Fruit & Seed



Loss of Fruit



Comparison between phenological measures on quadrats



- Good correlation between all measures of vegetative phenology
- Vegetation height never stop to increase until end of protocol sampling

	Height relative mean	Relative green index	% green
Height relative mean	1	/	/
Relative green index	0.71	1	/
% green	0.68	0.72	1

Conclusion on analyses

- For every measure of phenology the shift between 2010 and 2011 is **quite similar on average**.
- Measures on plant have a decrease of shift where as greenness measurements seems independent.

Mean of shift days between 2010 and 2011

Threshold	Green Index	% Greenness	height quadra	leaf length	Phenophase	Reproductive phenology
0.1	12	15	30	22	No flower	23
0.25	15	17	28	19	Closed flower	21
0.5	18	20	23	14	Open flower	13
0.75	26	11	10	13	Fruit & seed	7
0.9	12	7	-3	2	Loss of fruit	4
Mean	16	14	18	14		14

Conclusion on analyses

Protocol scales :

- Plot and subplot scales have **negligible effect** on observed variance of reproductive and vegetative phenology.
- A contrario, each monitored plant has its own "phenological phenotype" which can induce **strong variability from individual to another** even within a growth form type.

Two ways for a **better estimation of flora phenology** :

- Increase the **number of plant**
 - Increase the **number of sites**
- Growth forms "**grasses**", NG and GP, **are similar** in term of phenological development and shift between years
 - Growth forms "**Forbs**", FO and LG, have also a **similar pattern**
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Protocol survey

- First year was difficult for every user. But after 3 years of upgrading, protocol seems to be understandable by a large range of users.
- Variability of difficulties among measures, growth forms and period of sampling.

Advantages :

- Good quality results for phenology
- Test many types of phenological measures

Flaws :

- Botanist experience (identify growth forms species, phenophases)
- Time expensive (one day weekly for 5 month at least)
- Complex to implement (find a site, material installation)

Necessity to simplify the protocol for long term monitoring

Which measures should be retained?

Criteria

- **Informative** value about global change (reliability, robustness, sensibility)
- Data **quality** in long term (variability)
- Data **access** during sampling (data cost)

Which measures should be retained?

In forest

- Conserve the protocol

On alpine grassland

On scales :

- plots and subplots Duplicate could be cancelled
- Keep site surface sampled and the 105 plants monitored

On growth forms :

- Grazed and non grazed poaceae could be aggregated in grasses
- Leguminous and forbs could be aggregated in forbs

On greenness:

- % of greenness and plant height measurement could be abandoned
- Pictures could be taken directly on fixed quadrats anywhere on site.

further researches...

- Forest Protocol : Phenoclim
 - Sustain monitoring on sites to improve models on global change
- Protocol on alpine grassland
 - Sustain monitoring sites to improve models on global change
 - Increase the site network to get a better estimate of phenology and elaborated predictive models
 - Continue further analyses on climatic factors (snow cover, temperature, precipitation...)

Thank you.

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