Could climate extreme events elicit unexpected vegetation dynamics in mid-latitude alpine snowbeds?

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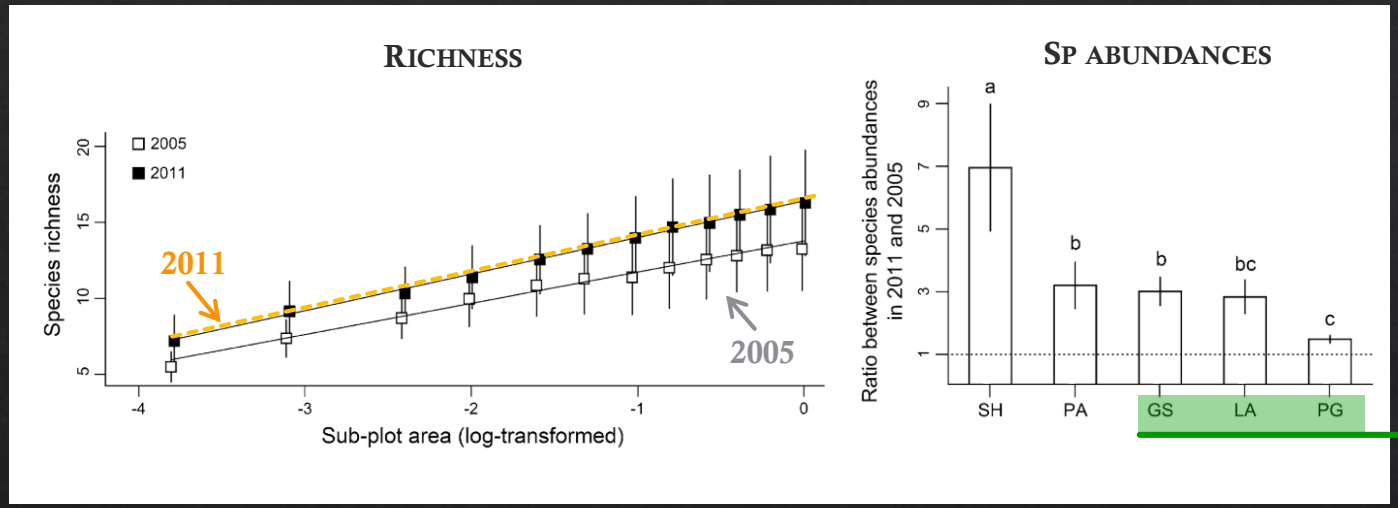
20th ITEX meeting
9-15 September 2019

UNIVERSITÀ DI PARMA

SNOWBEDS IN S-ALPS

↑ richness and abundance of both snowbed and non sb species



Carbognani et al., Alpine Botany, 2014

→ Release of **environmental limiting factors**

Snowbeds are among the most threatened communities in the Alps

Liberati et al., Alpine Botany, 2019

Gnaphalium supinum - GS

Leucanthemopsis alpina - LA

Primula glutinosa - PG

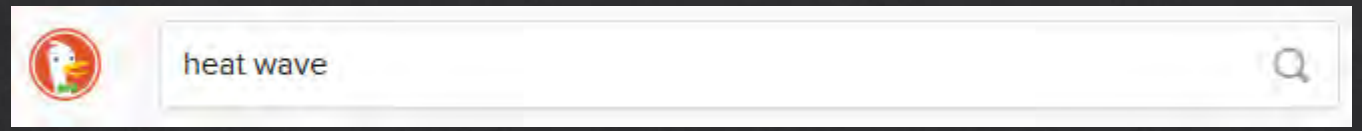
Further studies needed to disentagle effects of warming and earlier snowmelt

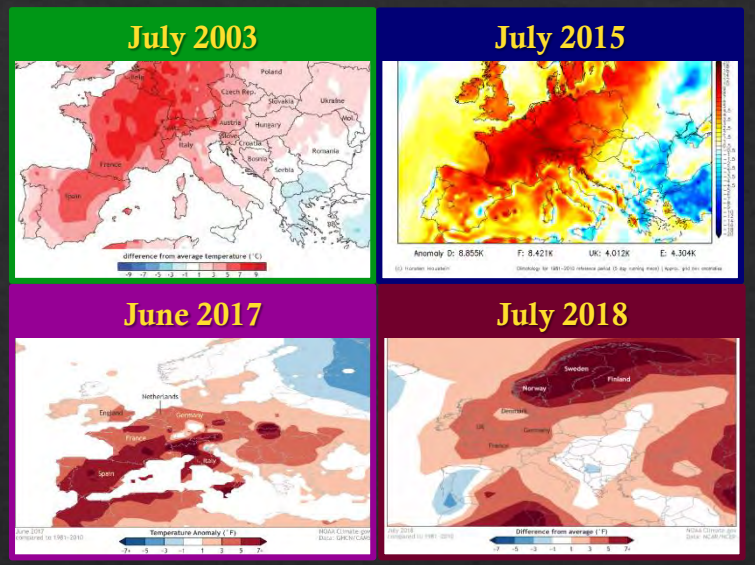
(Wipf and Rixen, 2010)

2012 start of manipulation experiments

5-6 days longer snow-free period per decade in the Northern Hemisphere since 1972-2000

(Dye, Hydrological Processes, 2002)

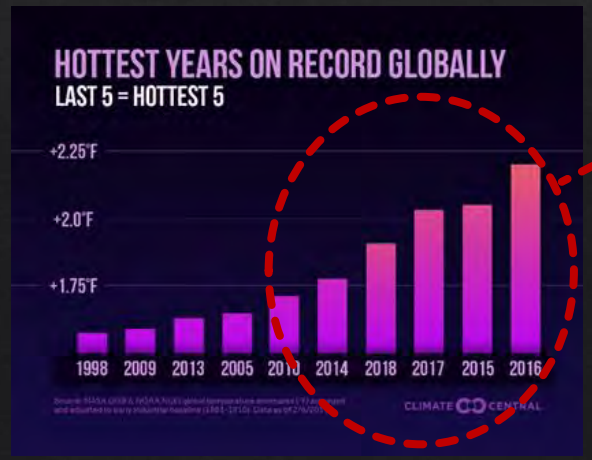




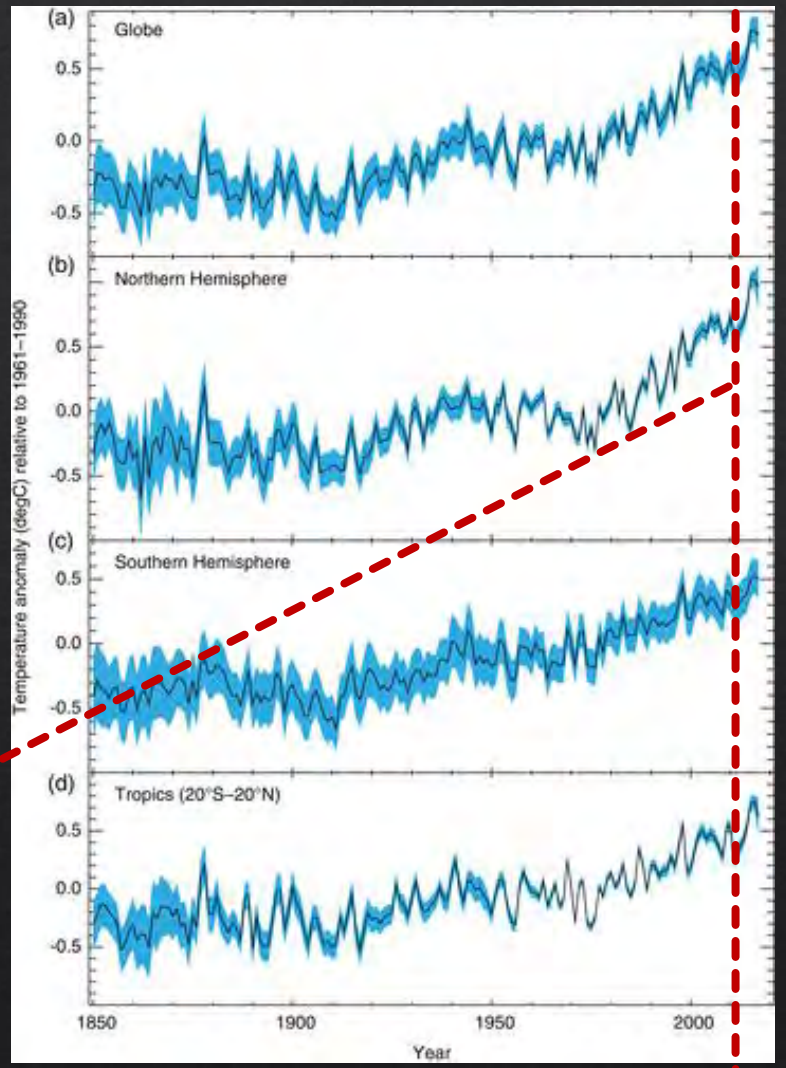
Pop ART → Pop eARTh

Heat waves associated to anticyclonic conditions lead to increased drought and high VPD

↑ frequency climate extremes



GLOBAL HEATING

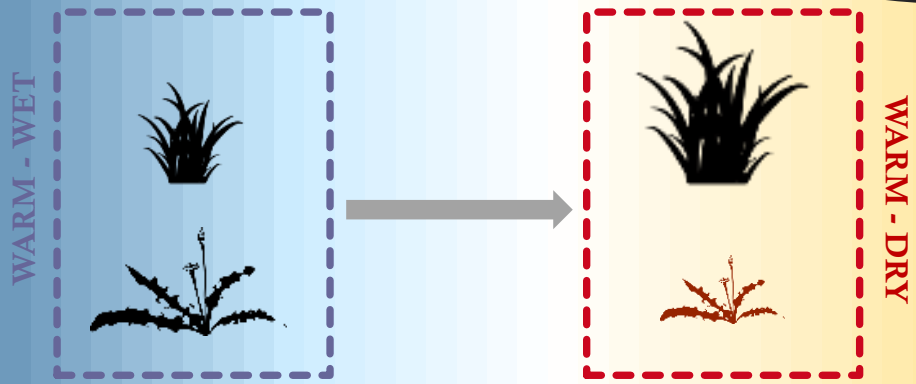


Kennedy et al., Royal Meteorological Society, 2018

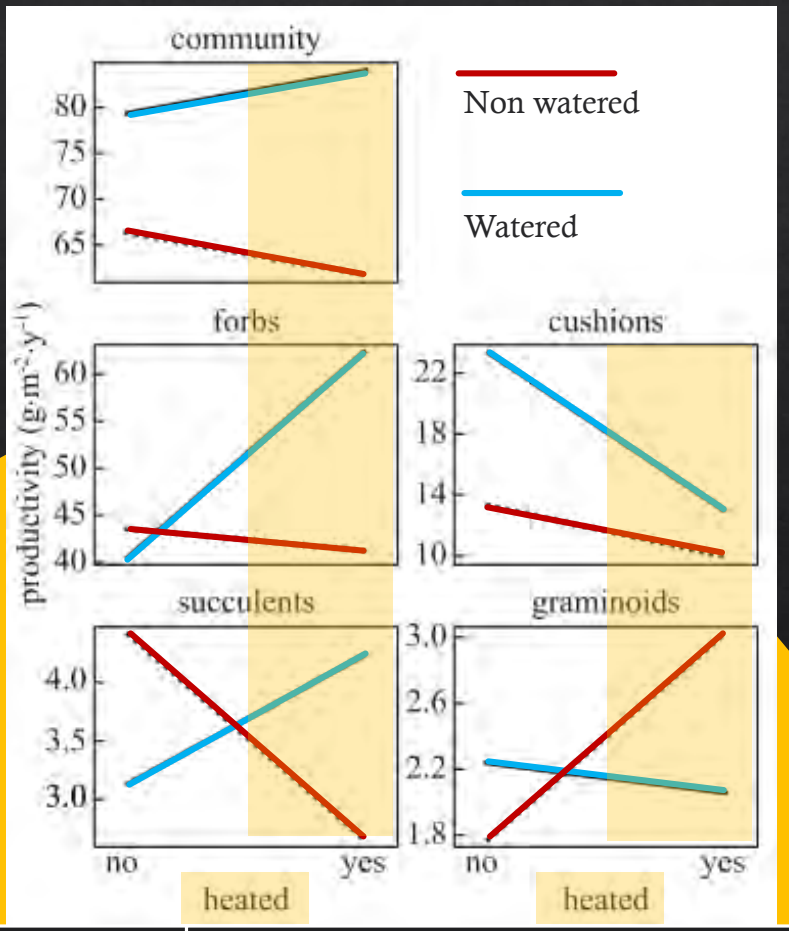
Sites soil moisture levels partly explained the difference of ecosystem responses to warming across space

(Elmendorf et al., Ecology Letters, 2012)

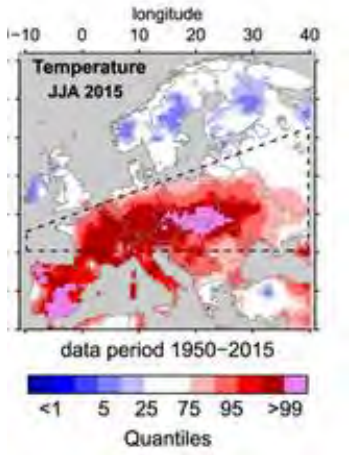
Responses to warming modulated by water availability within the same community:
"dry sensitive" *vs* "dry tolerant"



(Winkler et al., Ecology, 2016)

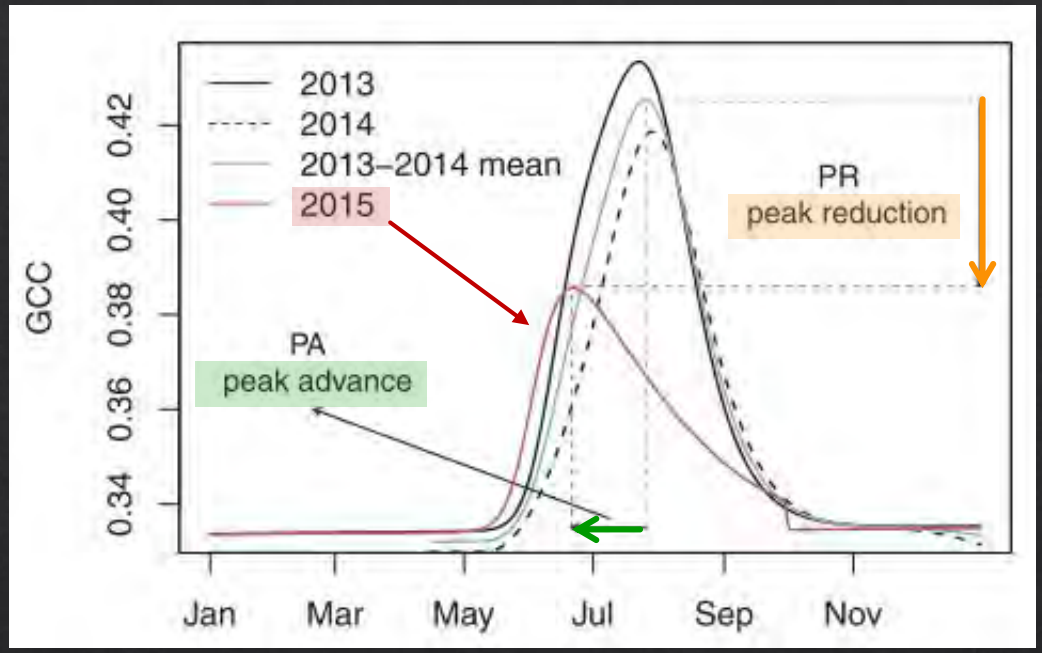


SUMMER 2015
Central Europe



- ↓ 31% reduction summer precipitation
- Temperatures 2nd highest in the 115-year record

Orth et al., Scientific Reports, 2016



(Cremonese et al., Agricoltural and Forest Meteorology, 2017)

20 days of heat wave + drought (July 2015) in subalpine grasslands in S-W Alps

- ↓ 39% reduction in greenness
- advanced senescence
- different responses of plant groups

NORTHERN APENNINES

August 2015, Mount Prado (2054 m) → *Salix herbacea* anticipated defoliation > 2 weeks

CARRY OVER EFFECTS

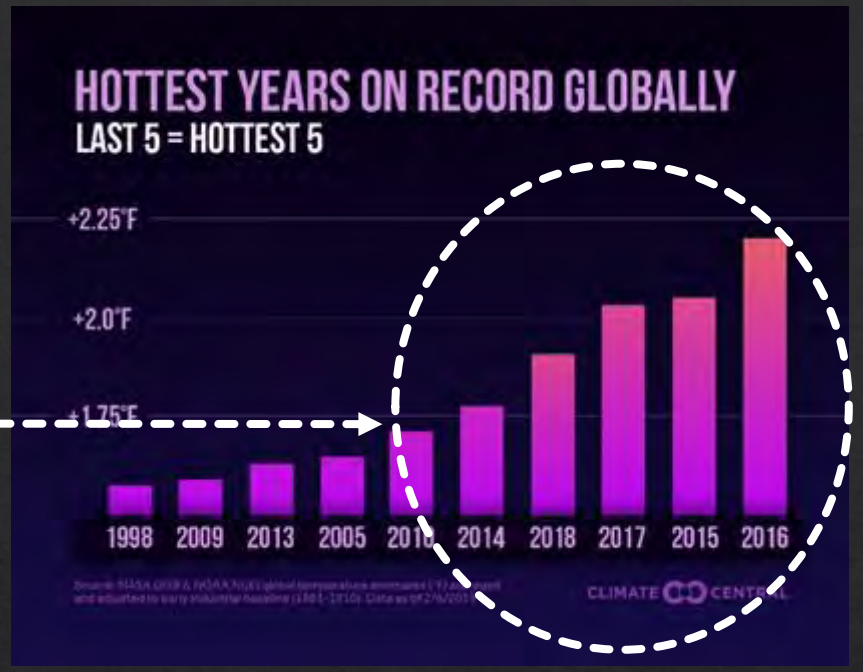
Y observed – Y expected

(Frank et al., Global Change Biology, 2015)

OBJECTIVES

Q1: To what extent alpine do snowbeds respond to increased temperature and early snowmelt in the **short term**?

2014-2018



Q2: Do climate extreme growing seasons (hot and dry) have an impact on the target plant community?

GAVIA PASS – 2700 m asl

Snowbeds

Mean T annual: -1.4 °C
Mean P annual: 1150 mm
~100 d snow-free

SNOWBED COMMUNITIES

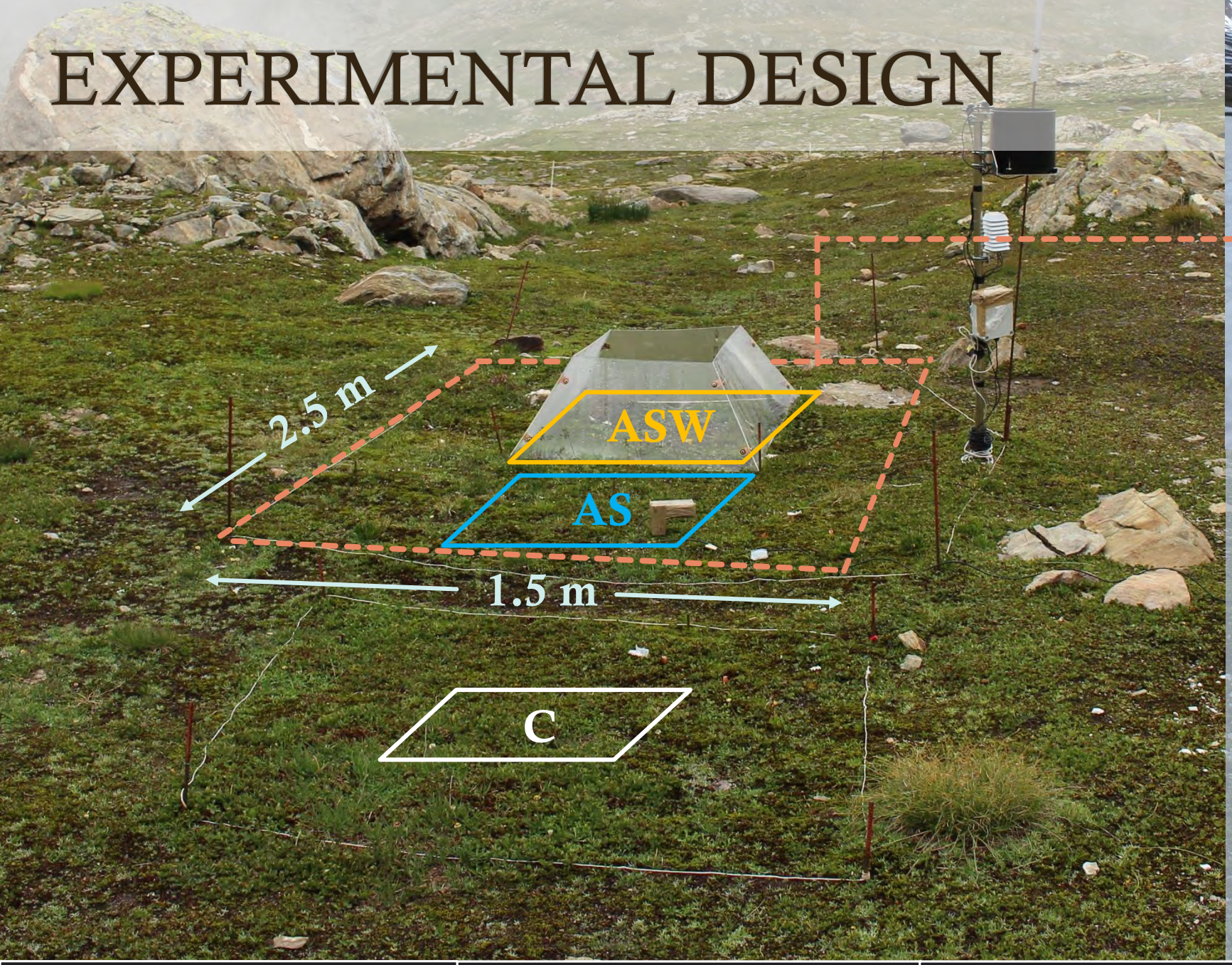
Moss-dominated (POL)

Polytrichastrum sexangulare

Shrub-dominated (SAL)

Salix herbacea

EXPERIMENTAL DESIGN



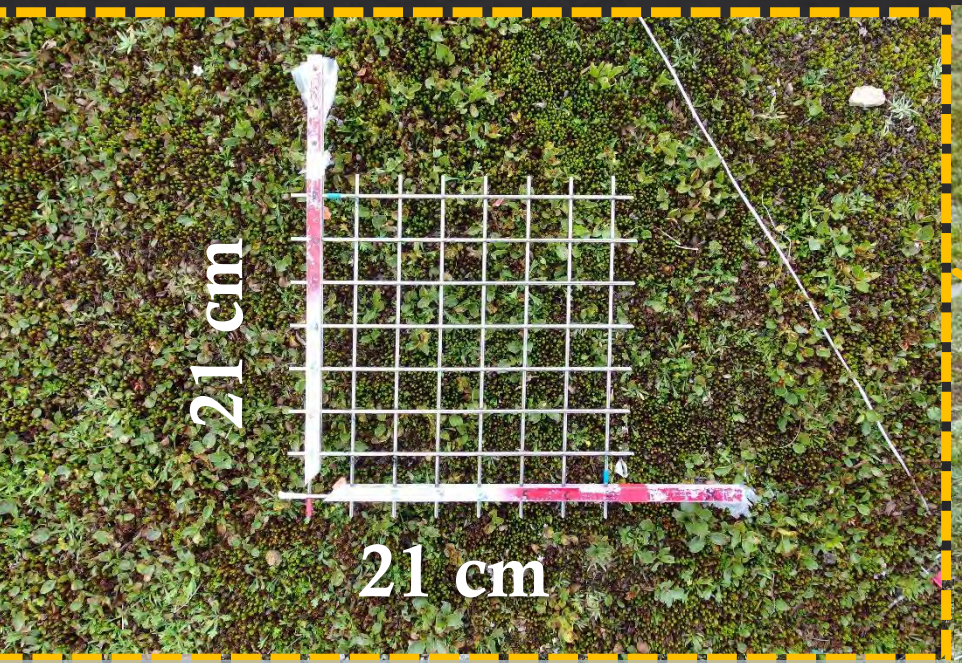
Treatements

- **C** - control
- **AS** - advanced snowmelt
- **ASW** - AS + warming

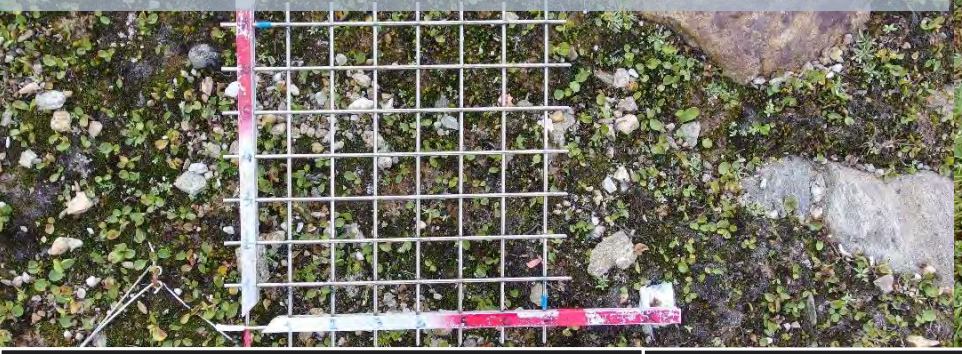
5 blocks

3 **SAL** + 2 **POL**

RICHNESS AND COVER



Point Intercept - 49 pins



STATISTICAL ANALYSIS - LMMs

- **RICHNESS** ~ year + trt + community + «two-way interactions» + (1|plot)
- **COVER** ~ year + trt + community + PFT+ «two-way interactions» + (1|plot)

2014 as a baseline

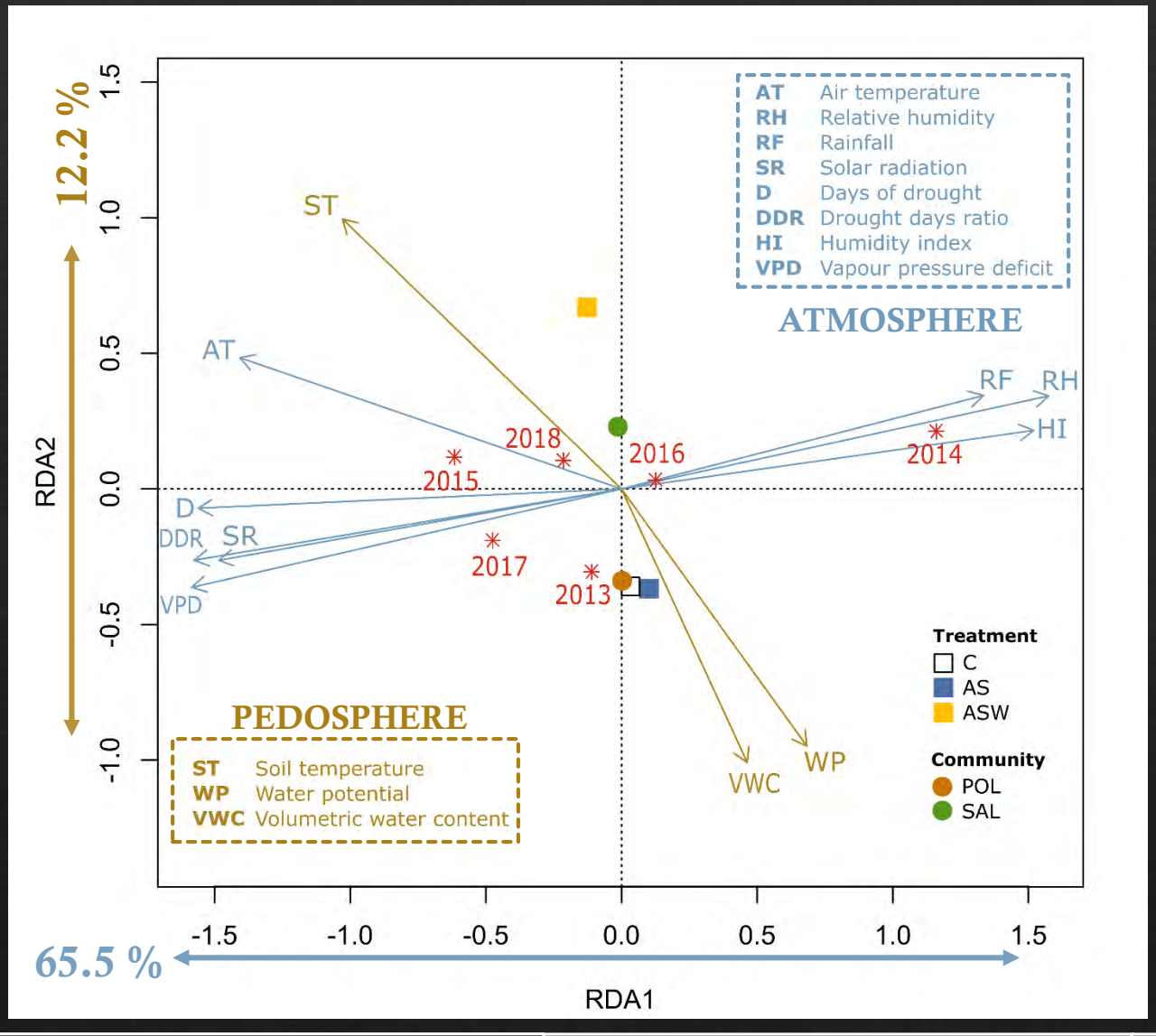
- *year* [4 –level, 2015-2018]
- *trt, treatment* [3-level, C AS and ASW]
- *community* [2-level; moss P and shrub S]
- *PTF, Plant Functional Type* [4-level, gram, forbs, shrub and moss]

- **COVER** ~ PFT + «environmental variables» + «two-way interactions» + (1|plot)

Xs of current and previous growing season (2013 included)

Y and **Xs** scaled at the plot level and check for collinearity

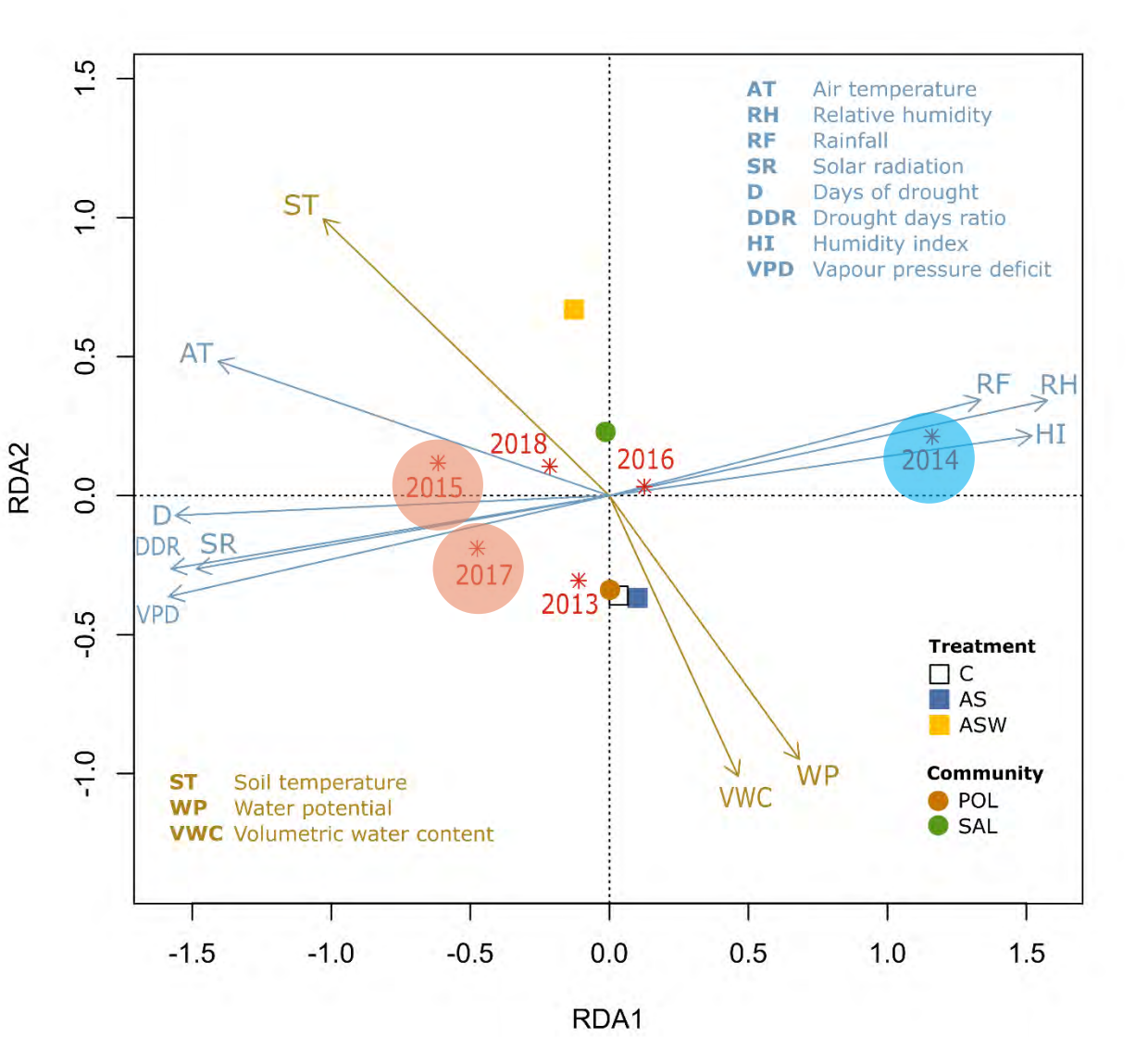
ENVIRONMENTAL FEATURES



Atm parameters explain most of the microclimatic variation

Years > Treatments > Communities

ENVIRONMENTAL FEATURES



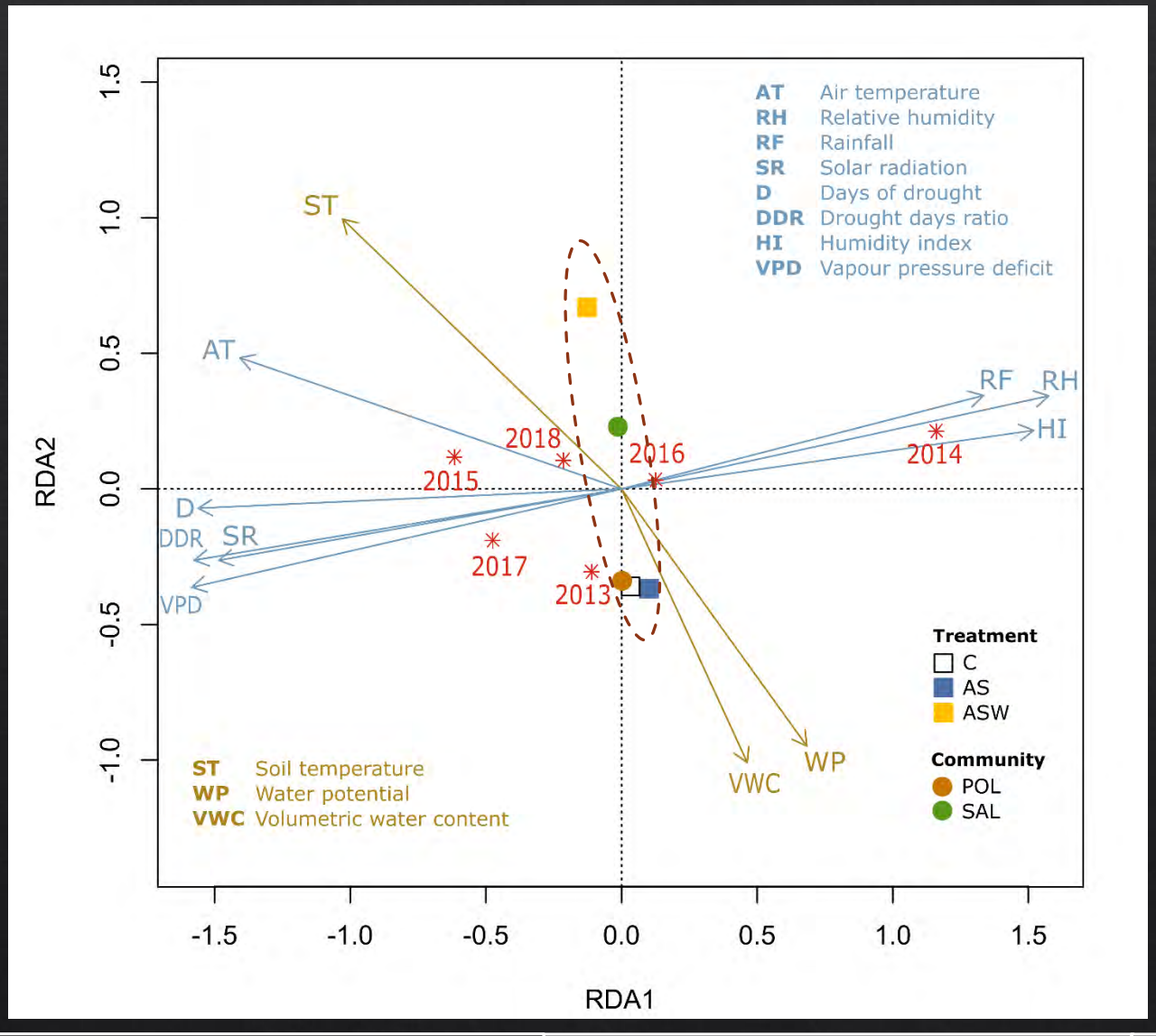
Atm parameters explain most of the microclimatic variation

Years > Treatments > Communities

2014 cool and wet

2015 and 2017 hot and dry

ENVIRONMENTAL FEATURES



Atm parameters explain most of the microclimatic variation

Years > Treatments > Communities

2014 (cool and wet) vs 2015 & 2017 (hot and dry)

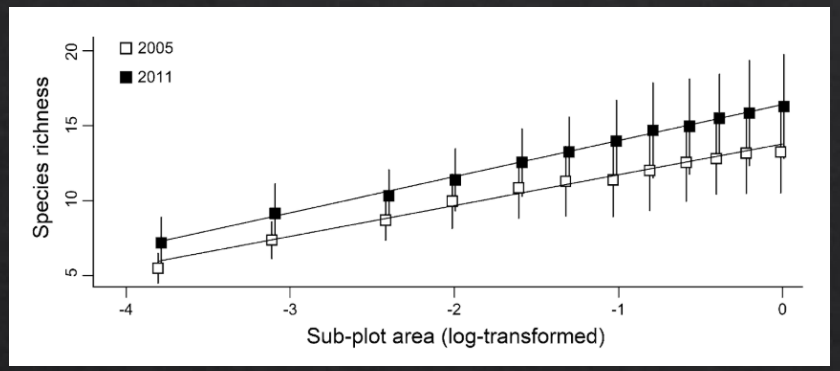
SAL
ASW

warmer and drier soil conditions

POL
AS & C

RICHNESS

- No treatment effect: equal ↑ across communities and treatments
- Gap filling
- No new species external to the existing pool



Carbognani et al., Alpine Botany, 2014

2018

0.27 ± 0.09 sp y^{-1}

2014

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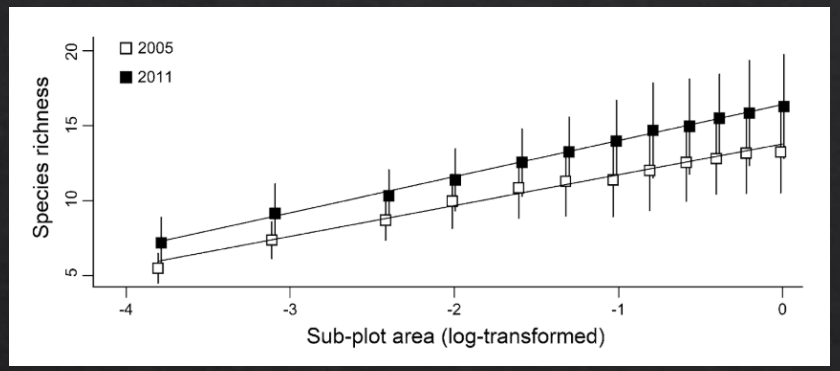

Carbognani et al., Alpine Botany, 2014

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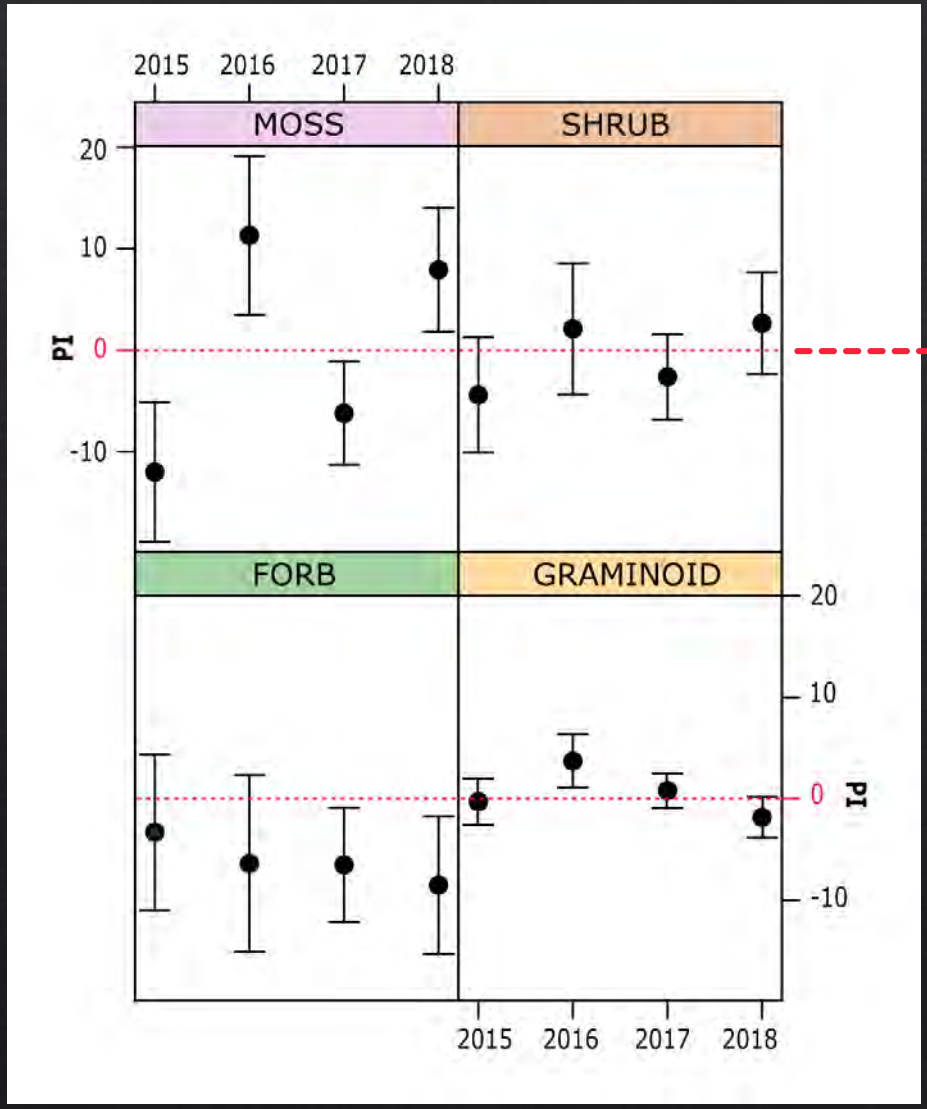
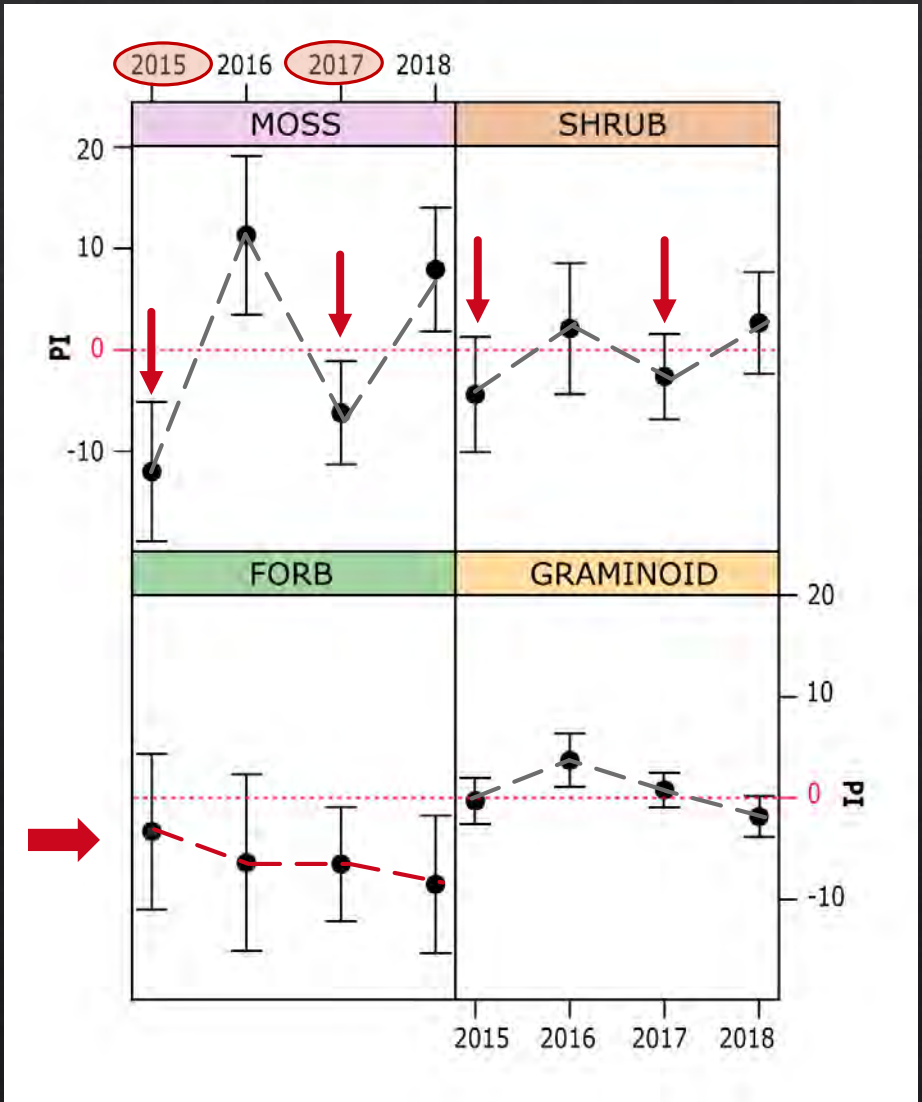
COVER – inter-annual variation



2014 baseline of Δ number of PI contacts

No treatment effect
~ year, Plant Functional Type and PFT * year

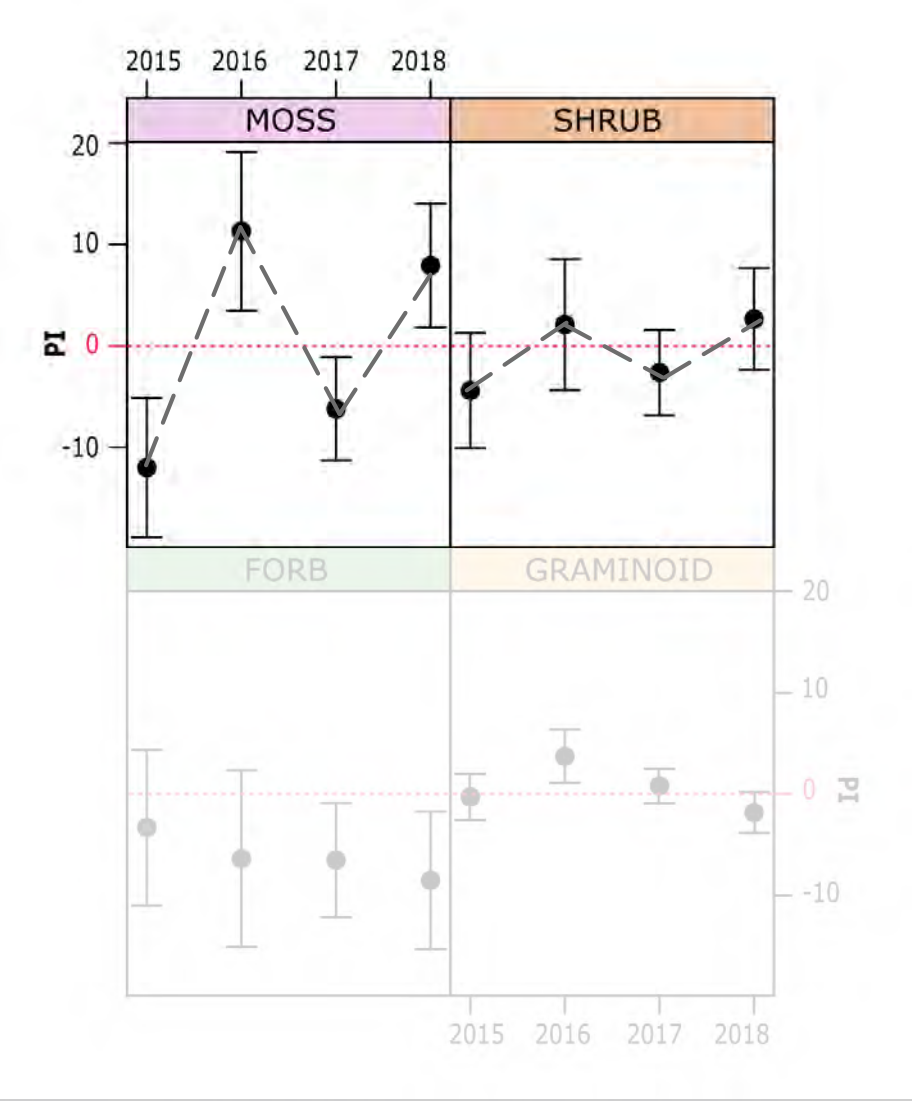
COVER – inter-annual variation



~ year, PFT and year * PFT

Shrubs and mosses → major oscillation
Forbs → consistent decline

COVER – inter-annual variation



~ year, PFT and year * PFT

Mosses and shrubs → major oscillation

Mosses

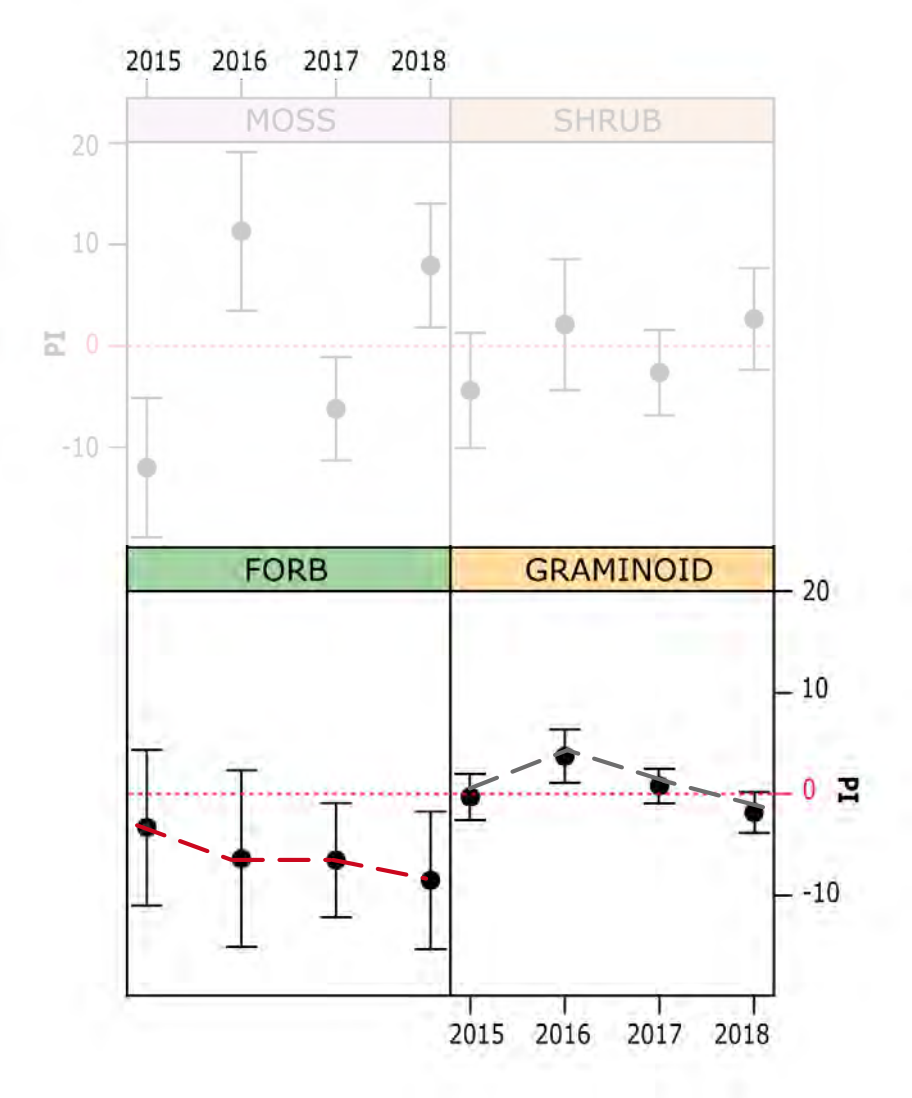
Hydration/desiccation process

(Proctor et al., The Bryologist, 2007)

Shrubs

Strong year-to-year response to climate conditions
↓ dimension and number of leaves

COVER – inter-annual variation



~ year, PFT and year * PFT

Mosses and shrubs: major oscillation

Forbs → Constant decline

Change related to last years:
↑ until 2011 in the same area.

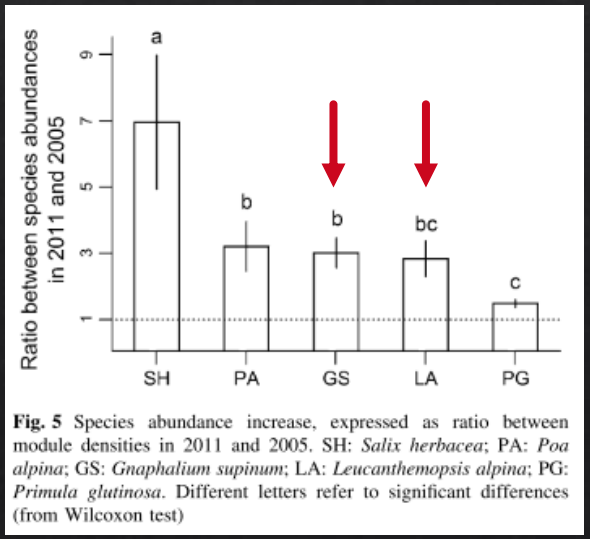
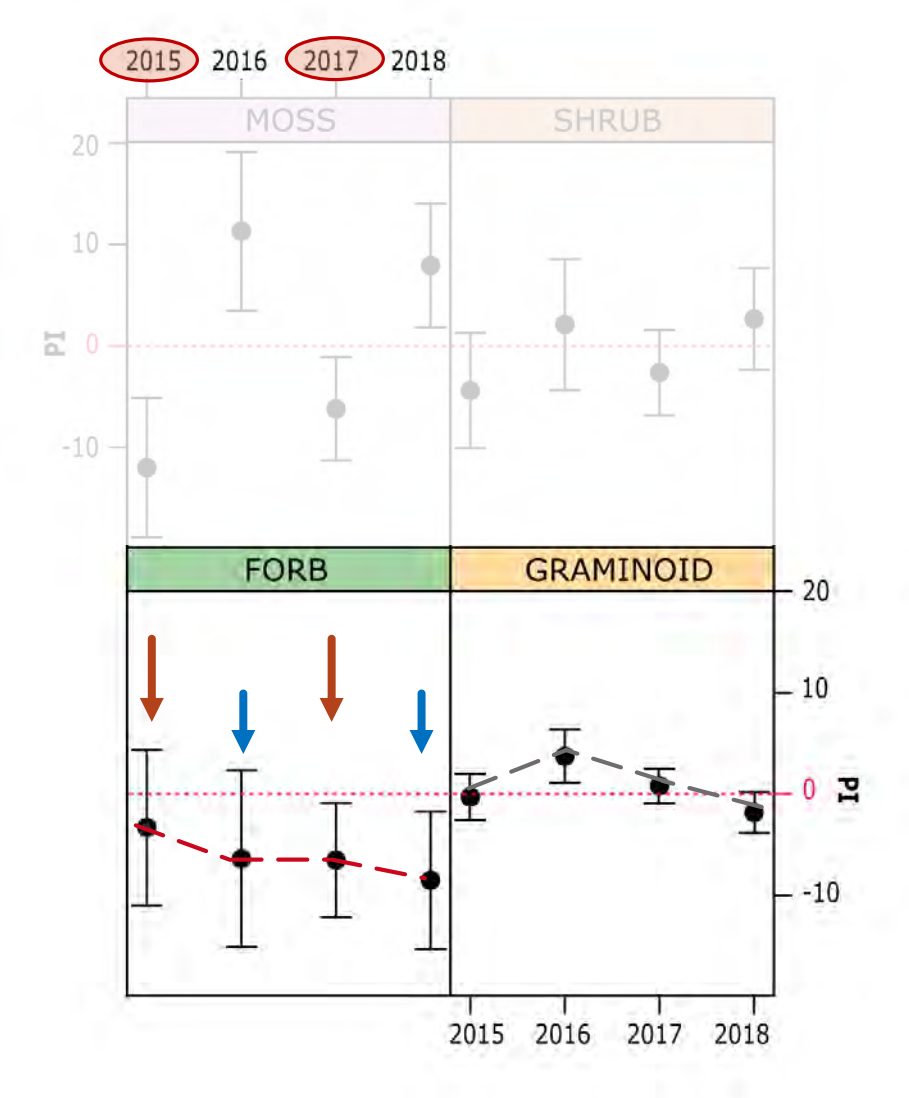


Fig. 5 Species abundance increase, expressed as ratio between module densities in 2011 and 2005. SH: *Salix herbacea*; PA: *Poa alpina*; GS: *Gnaphalium supinum*; LA: *Leucanthemopsis alpina*; PG: *Primula glutinosa*. Different letters refer to significant differences (from Wilcoxon test)

(Carbognani et al., Alpine Botany, 2014)

COVER – inter-annual variation



~ year, PFT and year * PFT

Mosses and shrubs: major oscillation

Forbs → Constant decline

Negative response to drought episodes and heat-waves both in observational and manipulation studies in the Alps

Cremonese et al., Agricoltural and Forest Meteorology, 2017
De Boeck et al., New Phytologist, 2016

Veronica alpina

No recovery of forbs.

COVER – environmental variables

Effects on the STANDARDIZED COVER	df	F	P
Plant Functional Type	3,253	0.00	1.000
SR, solar radiation – current year	1,253	5.11	0.025
SR, solar radiation – previous year	1,253	35.99	<0.001
ST, soil temperature – previous year	1,253	6.63	0.011
PFT × SR-c	3,253	5.71	<0.001
PFT × SR-p	3,253	21.39	<0.001

PFT interaction with SR

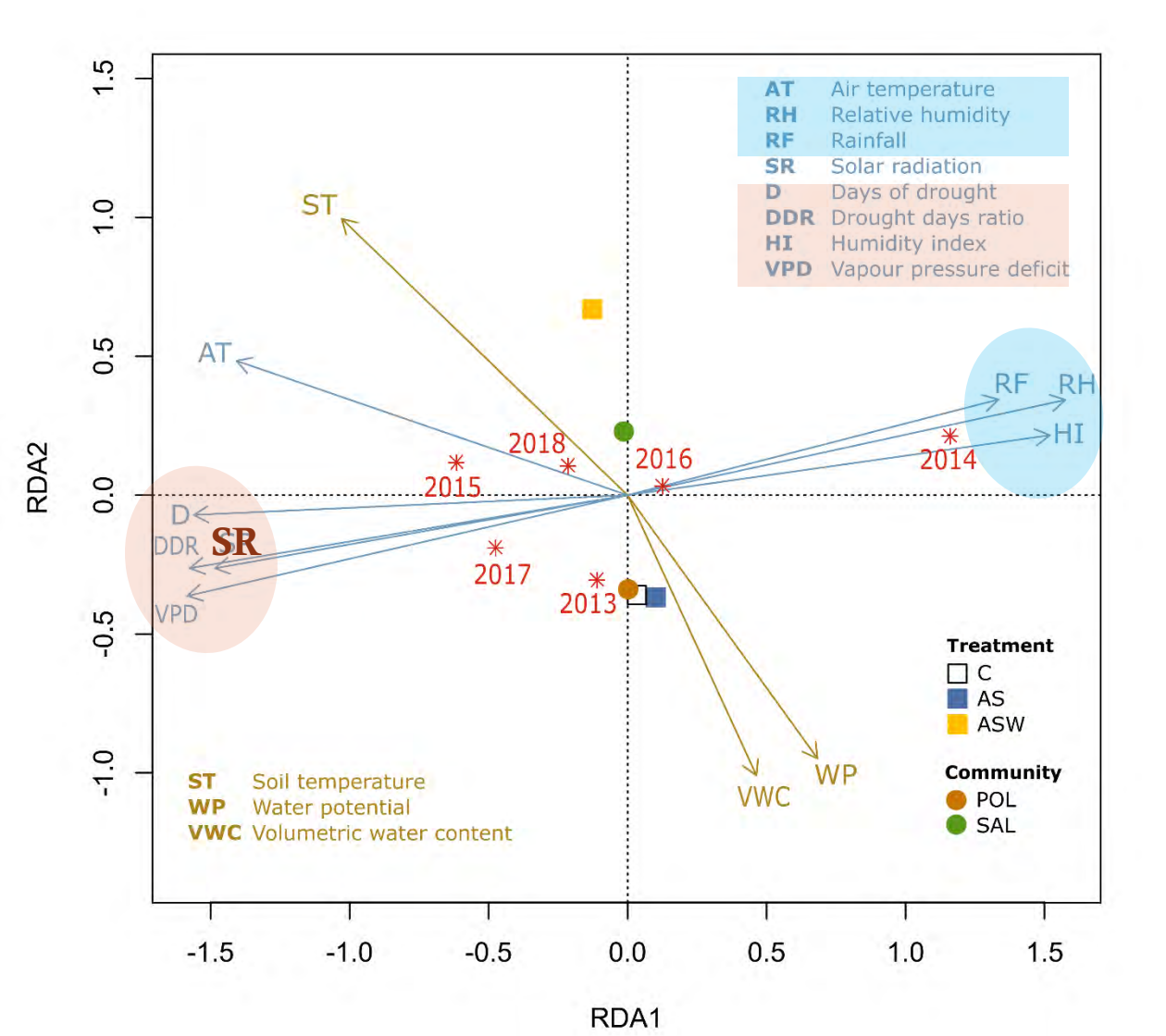
Y and **Xs**
scaled at the plot level

Xs of current and previous growing season (2013 included)

SR and ST main environmental drivers: positive relation

Effects of previous growing season

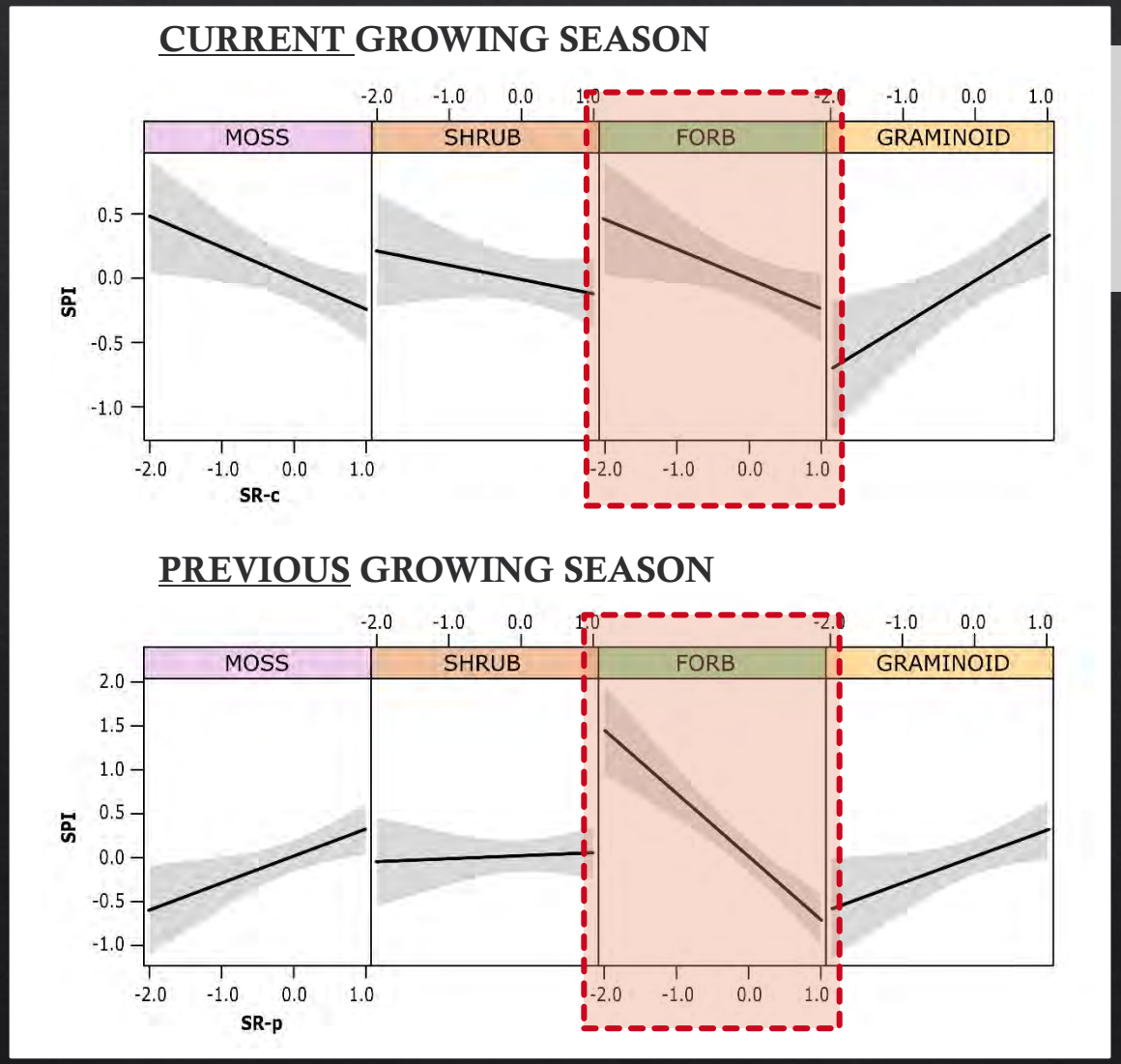
COVER – environmental variables



SR positively related with atm dryness variables and negatively with humidity

SR → hot and dry conditions

COVER – environmental variables



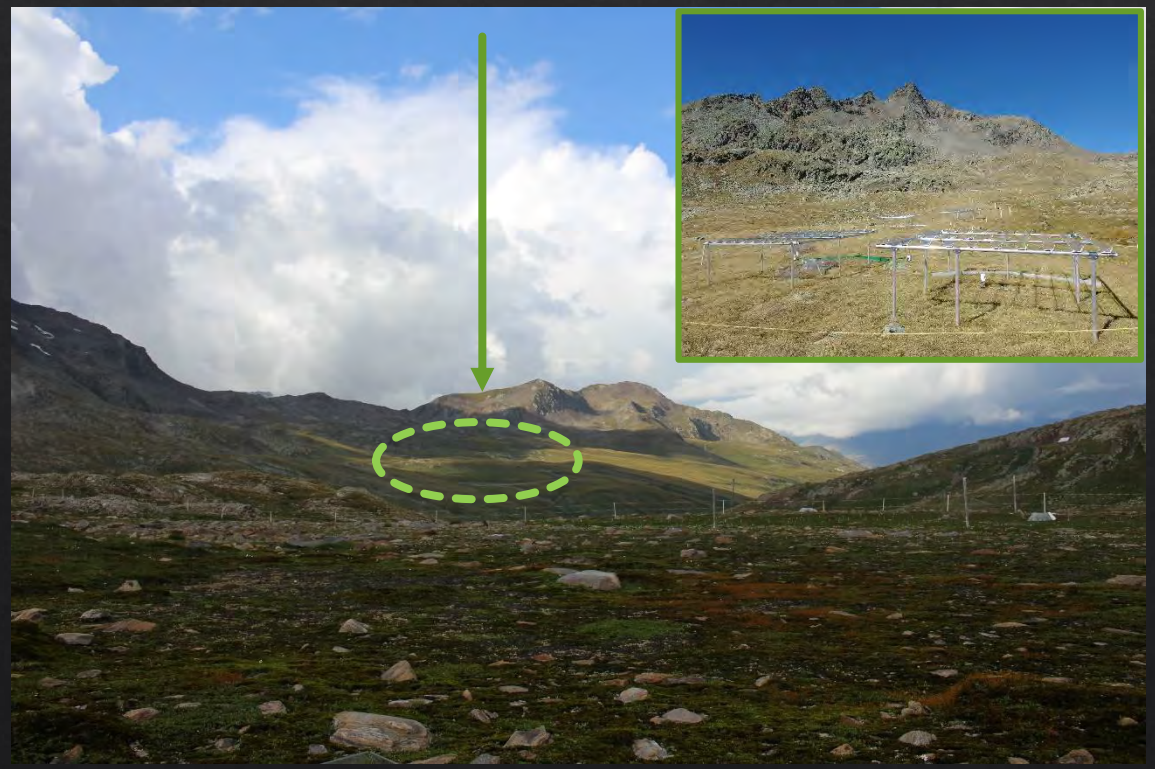
Forbs → negative response to SR in both current and previous years

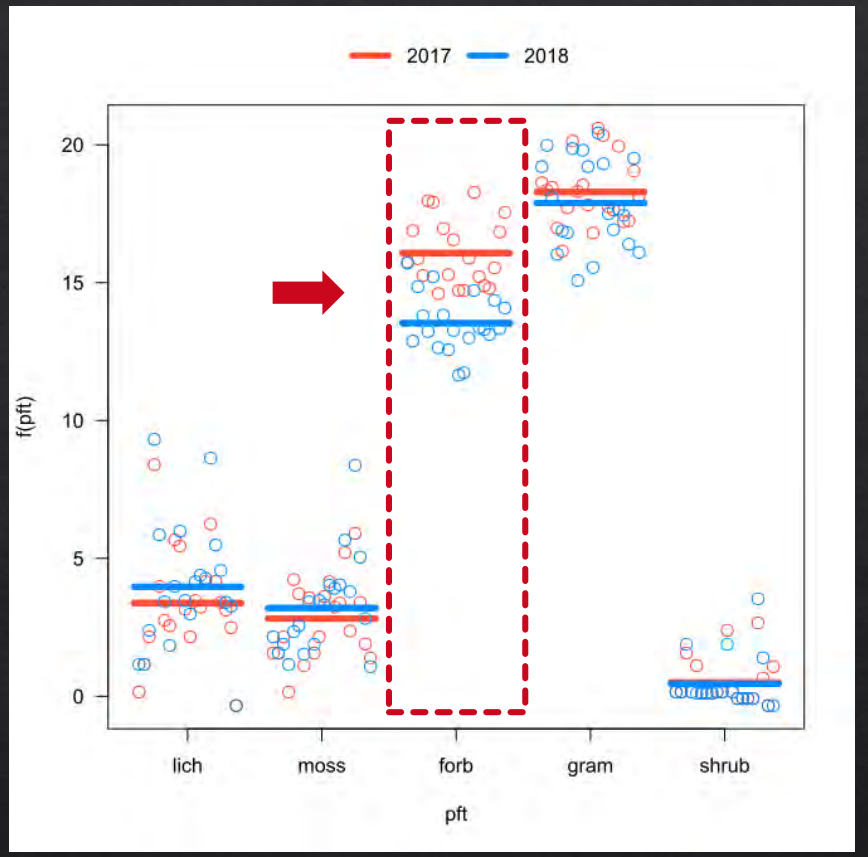
Opposite response of graminoids

Similar ↓ in *Carex curvula* grassland (precipitation manipulation experiments) in the same valley of snowbeds

COVER – environmental variables

Similar ↓ in *Carex curvula* grassland (precipitation manipulation experiments) in the same valley of snowbeds

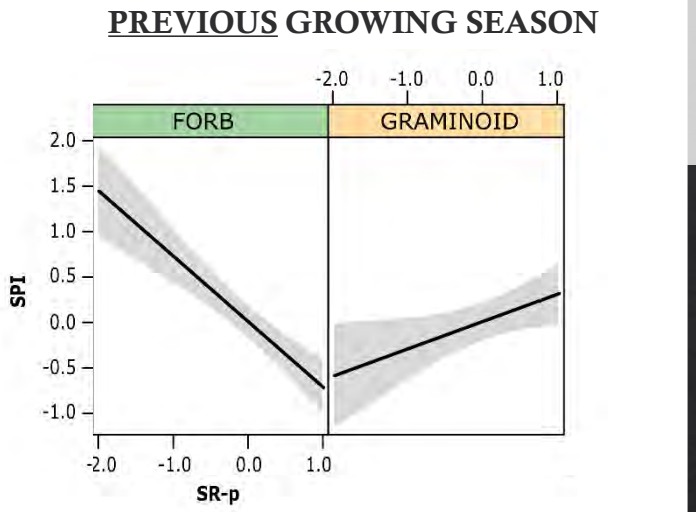




↓ total number of PI forbs in 2018

(20 permanent plots)

COVER – environmental variables



Gnaphalium supinum

Forbs → negative response to SR of previous years

Carry-over effect

17 days of simulated heat-wave and drought in alpine grasslands

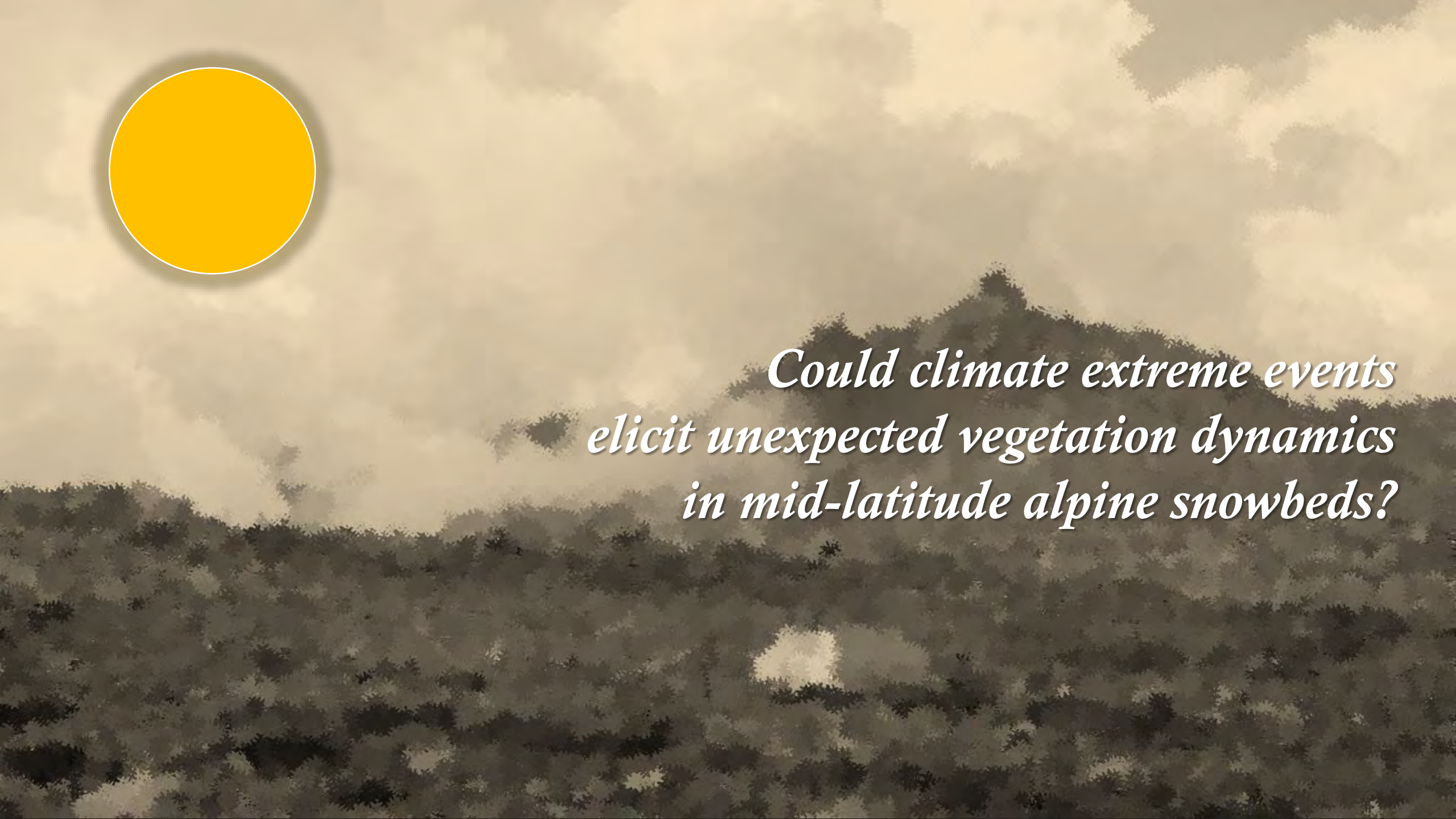
Subsequent 2 years, in manipulated areas:

- ↓ green cover
- ↓ biomass
- Forbs slower recovery than graminoids

(De Boeck et al, Frontiers in Plant Science, 2018)

Reached mortality thresholds
Reduced nutrient acquisition
Altered allocation patterns
…..

HP FOR FORBS ↓


Could climate extreme events
elicit unexpected vegetation dynamics
in mid-latitude alpine snowbeds?

CONCLUSIONS

To what extent do alpine snowbeds respond to warming and early snowmelt in the short term?

- Treatments did not have any effect → years of the study period too hot
- Richness increases → natural dynamics of gap filling driven by species already present in the existing pool

CONCLUSIONS

Do climate extreme growing seasons (hot and dry) have an impact on the target plant community?

- Effects of current and previous growing season conditions, with solar radiation (hot and dry conditions) being the major driver
- Differential responses across PFTs (sensitive *vs* tolerant) and hp of carry over effects → changes future structure and composition of the community
- Necessity to address lagged and legacy effects more consistently in future experiments in view of increasing frequency of climate extreme events

THANK YOU!

ENVIRONMENTAL VARIABLES

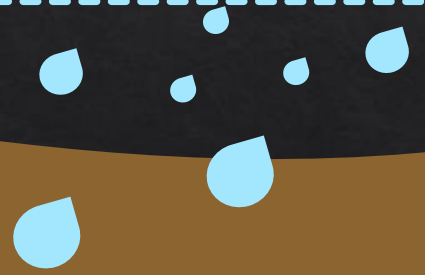
ATMOSPHERE

AT – Air temperature
RH – Relative humidity
RF – Rainfall
SR – Solar radiation

VPD – Vapour Pressure Deficit
HI – Humidity index
D – Days of drought
DDR – Days of drought ratio

PEDOSPHERE

ST – Soil Temperature
VWC – Volumetric Water Content
WP – Water Potential



ENVIRONMENTAL VARIABLES

ATMOSPHERE

AT – Air temperature
RH – Relative humidity
RF – Rainfall
SR – Solar radiation

Vapour Pressure Deficit

VPD = ((100 - RH) / 100) * SVP

→ SVP (Pa) = $610.7 * 10^{7.5 * AT / (237.3 + AT)}$

Humidity index

HI = RF/PET

→ $PET = 0.0018 * (25 + AT)^2 * (100 - RH)$

Days of drought

days in the longer period without rainfall

DDR – Days of drought ratio

Ratio between the # days in the longer period without rainfall and total # days from snowmelt to the growing season peak

VPD - Murray, J. Appl. Meteorol., 1967

HI - Liu et al., PNAS, 2018