IDENTIFYING THE ENVIRONMENTAL DRIVERS OF CARBON FLUXES – A STEP TO ASSESS CLIMATE CHANGE IMPACTS ON ECOSYSTEMS

LifeWatch Thematic Service Workshop
Climate Change Impacts on Biodivesity Patterns

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Lecce, Italy

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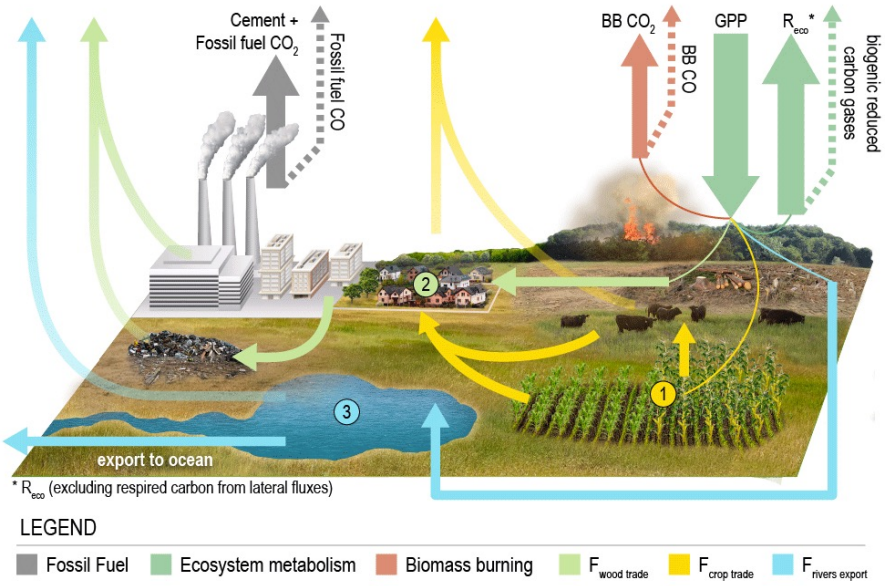
and the Critical Zone collective

Consiglio Nazionale delle Ricerche – Istituto di Geoscienze e Georisorse

WHY CARBON DIOXIDE (CO_2) FLUXES?



Byrne et al., 2023 - ESSD

Need for coordinated actions to monitor, understand and manage not only anthropogenic emissions emissions, but also natural response to global changes

The CO_2 is a key climate-change agent and the major responsible of global warming, together with methane (CH_4) and nitrous oxide (N_2O). Current atmospheric concentrations are the sum of anthropogenic emissions and natural emission/uptake, which in turn are influenced by climate and other environmental changes. The quantitative knowledge of some of the current and future contributions to natural CO_2 exchanges has large uncertainties.

Paris agreement (2015)

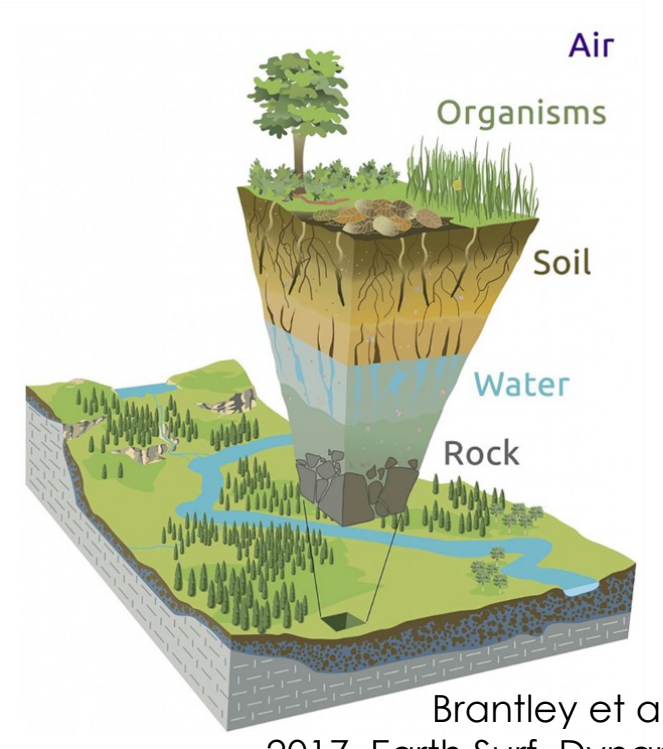
COP28 (2023)

Global Greenhouse Gas Watch - G3W coordinate by the World Meteorological Organization (2028-2050)

MONITORING CARBON DIOXIDE (CO_2) FLUXES

	Accumulation chambers	Eddy covariance towers	Drones and satellites
Gross Primary Production (GPP)	Direct measurement	Modeled	Modeled/Proxied
Ecosystem Respiration (ER)	Direct measurement	Direct measurement at nighttime, modeled at daytime	Modeled

THE CRITICAL ZONE



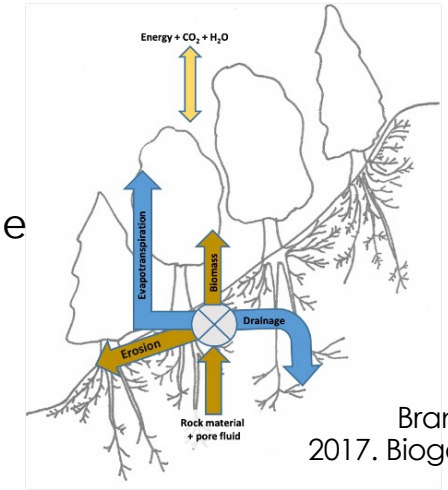
Brantley et al., 2017. Earth Surf. Dynam

- The Critical Zone is the highly complex system going from the top of the vegetation canopy to the unperturbed bedrock, i.e. to the bottom of the surface aquifer

The Critical Zone is where rocks meet life

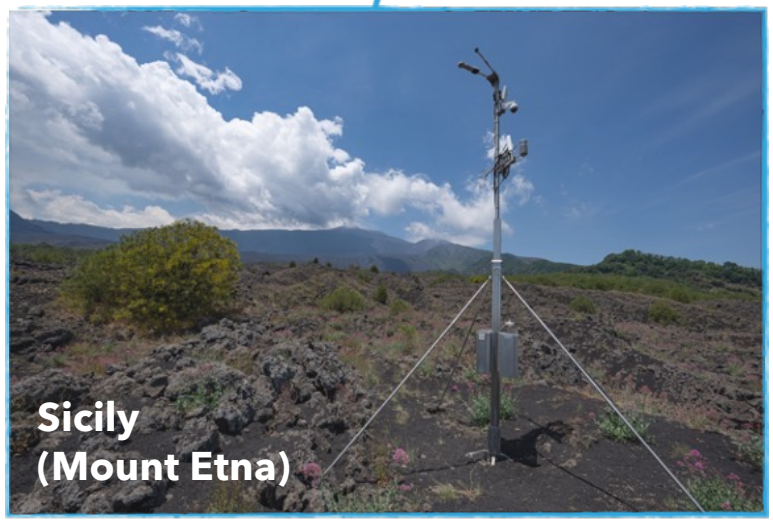
- It provides all the ecosystem services supporting life, and therefore its integrity is "critical" to the living communities and human wellbeing.

- It is the "living reactor", that links the subsurface with the atmosphere. In the CZ fluxes of matter (e.g. water and carbon) and energy are either generated or modified.



Brantley et al., 2017. Biogeosciences

CRITICAL ZONE OBSERVATORIES



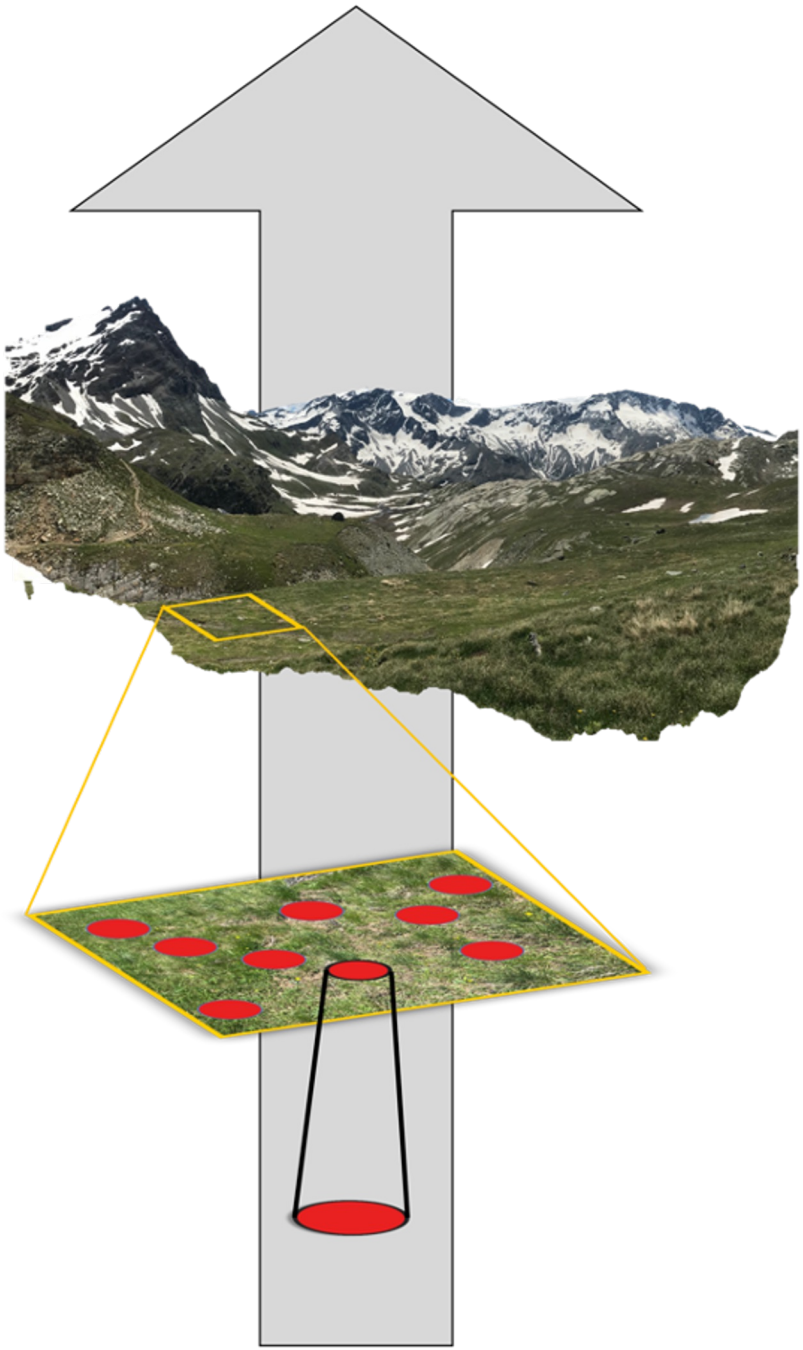
- Do plant and microbial diversity reflect into variations of CO_2 fluxes in these environments?
- What are the drivers of CO_2 fluxes at different spatial and temporal scales?
  - Do they change with the spatial scale?
  - How can we upscale the local results?
  - What is the role of seasonal and annual variations?

Scales

Landscape
(ecosystem)

Plot
(community)

Point
(individuals)

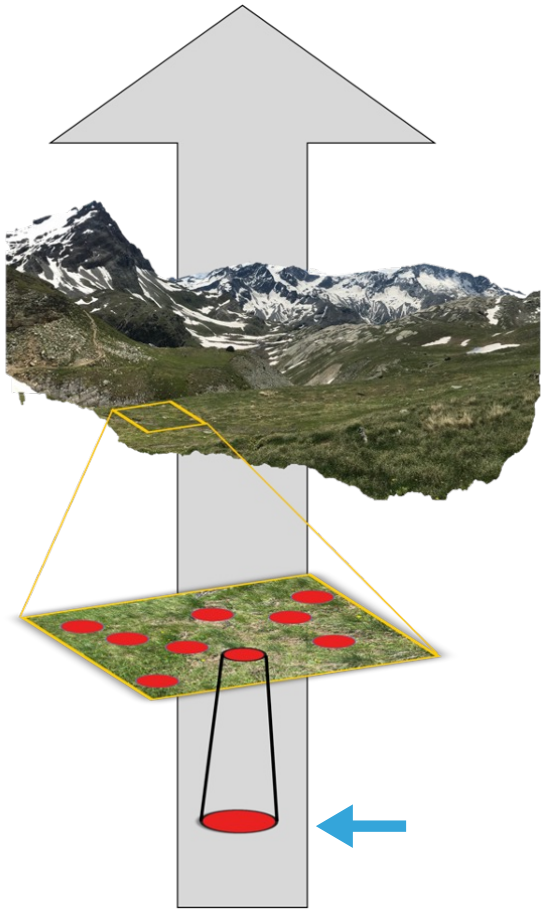


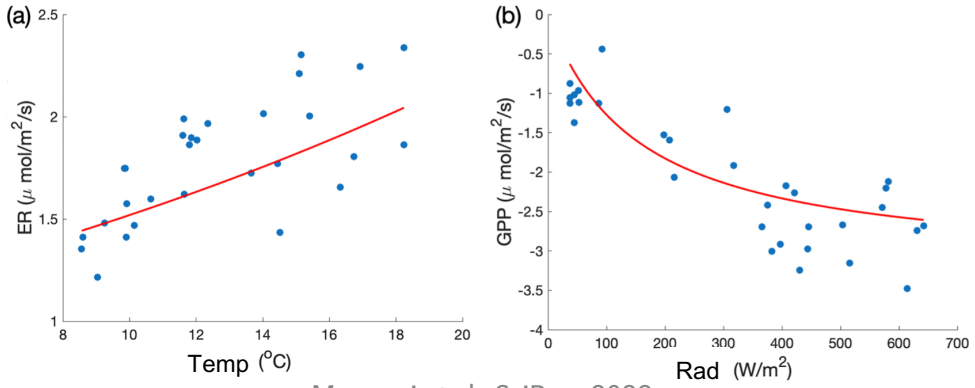
Instruments

POINT FLUXES

- The classical drivers well reproduce flux patterns over one single point and short times

$$ER = ae^{bTemp} \qquad GPP = \frac{F\alpha Rad}{F + \alpha Rad}$$





Magnani et al., SciRep, 2022

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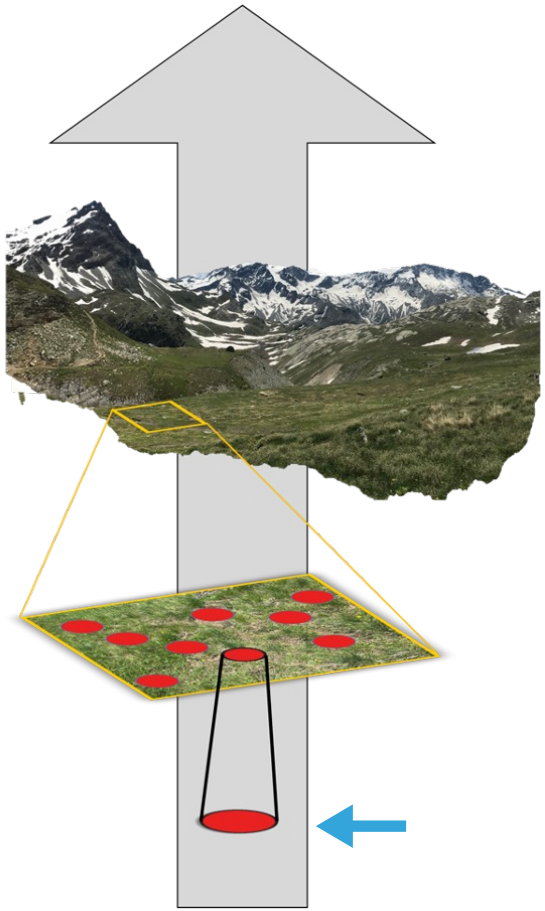
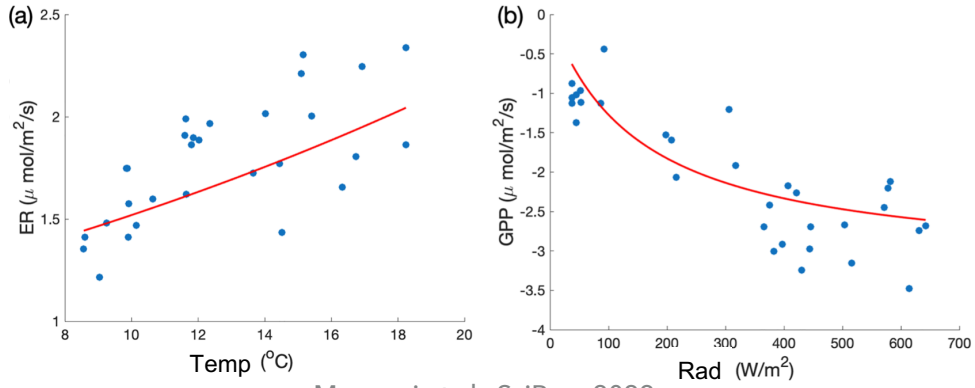
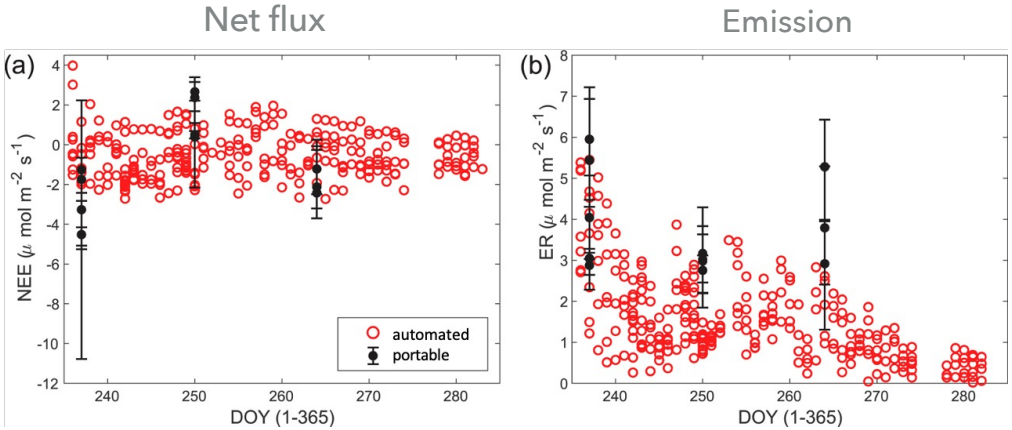




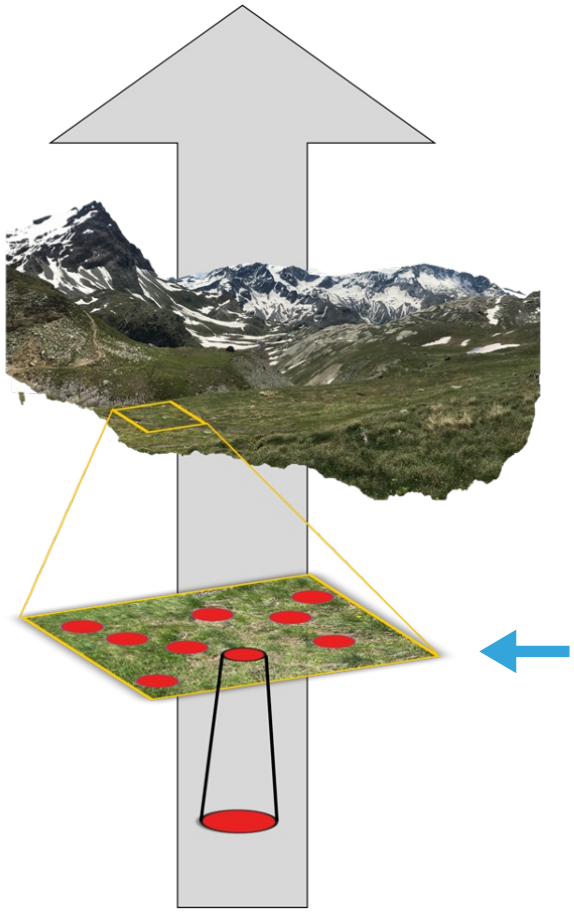
Magnani et al., SciRep, 2022

- At the point scale, plant/bacterial diversity is reflected in the heterogeneity of fluxes: significant point-to-point flux difference, that decreases with vegetation senescence

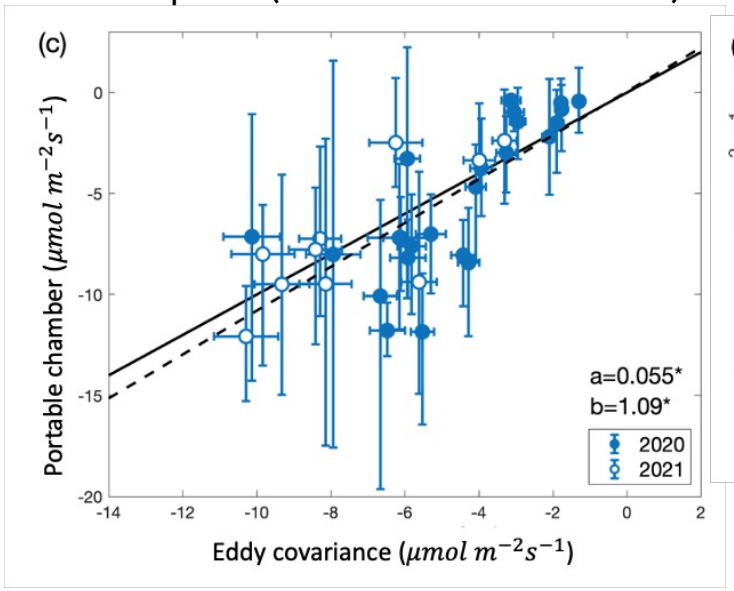


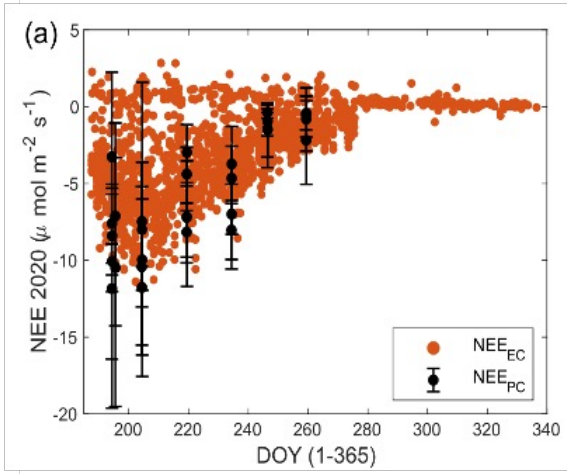
Vivaldo et al., AtmEnv, 2023

PLOT FLUXES



- Even thought the biological diversity is responsible of flux heterogeneity, few (5 to10) measurements are sufficient to represent the range of variability within the plot (about 20 x 20 m^2).





Vivaldo et al., AtmEnv, 2023

- To model the ensemble of points at the plot scale multi-regression models are needed

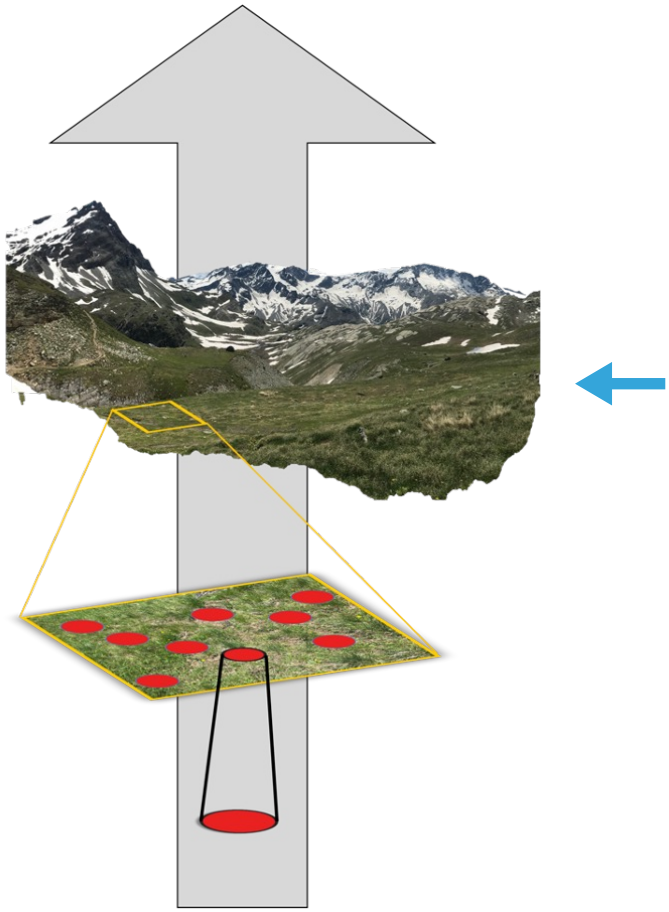
$$ER = (a_0 + a_1 DOY^{*} + a_2 soil\ moisture)e^{bTemp}$$

$$GPP = (A_0 + A_1 DOY^{*} + A_2 soil\ moisture)\frac{F\alpha Rad}{F + \alpha Rad}$$

Magnani et al., STotEn, 2020

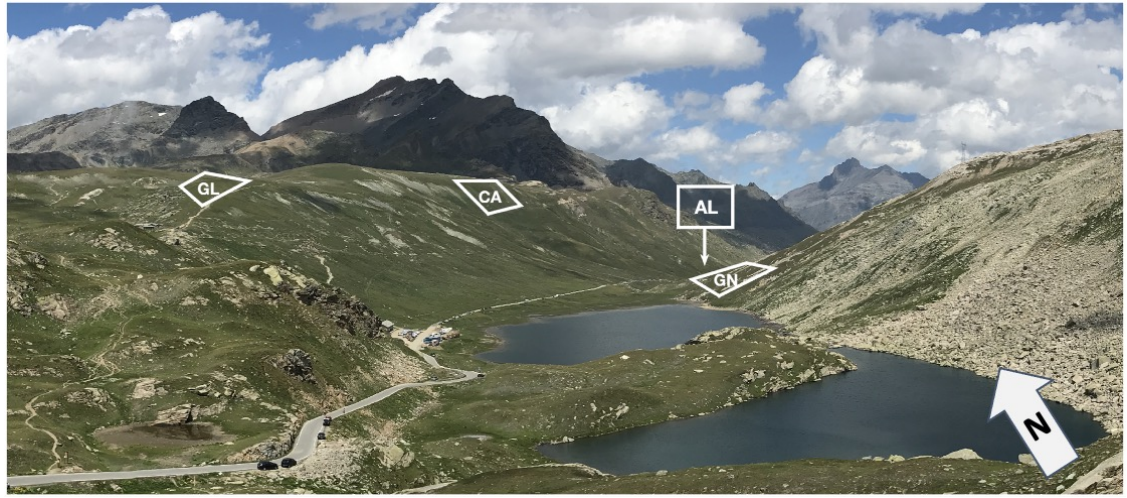
* interpreted as a proxy of phenology

LANDSCAPE FLUXES



- Parameterizing the model for 4 years (2018-2021) and 4 plots characterised by different soil origins
  - Carbonate rocks
  - Gneiss rocks
  - Glacial till
  - Alluvial deposits

Spatial variability (plot-to-plot) < Temporal variability (year-to-year)



Lenzi et al., PlosOne, 2023

BEYOND THE LANDSCAPE...

- Drones: flights in 2023 in the Gran Paradiso National Park area to be integrated with flux chamber measurements. Stay tuned!

- Satellites: substitution of in situ measured drives with remotely sensed variables. Measurements of primary production are reproduced by 3 factors that agrees with in situ models (Vicario et al., in review):
  - Solar radiance (surface solar radiation downwards)
  - moisture index (computed water pressure deficit)
  - Phenological index (MCARI/MSAVI, i.e. the ratio between chlorophyll and total leaf pigment)

Thanks for your attention!

1. **The CO_2 fluxes provide information about the effects of climate changes on ecosystems**

2. **Plant (and possibly microbial) diversity is a key factor in the spatial and temporal variations of CO_2 fluxes in the Alpine and Arctic environment.**

3. **This effect is observed at the point scale (level of individuals): different species or groups of species are associated with statistically different fluxes. At the plot to landscape (community level), temporal variations are dominant with respect to spatial heterogeneity (i.e. the dynamic response of communities is more important than the specific composition).**

Acknowledgements

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