Winter CZ: measuring CO_2 fluxes and microbiological processes in the High Arctic winter At the Bayelva Critical Zone Observatory (Svalbard)

Participants:

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WHY THIS PROJECT ?

Arctic CO_2 fluxes = crucial component of the global greenhouse gas balance

Summer = the tundra is (still) a weak carbon sink

Winter = the tundra could act as a (weak?) carbon source

Many summer measurements and studies

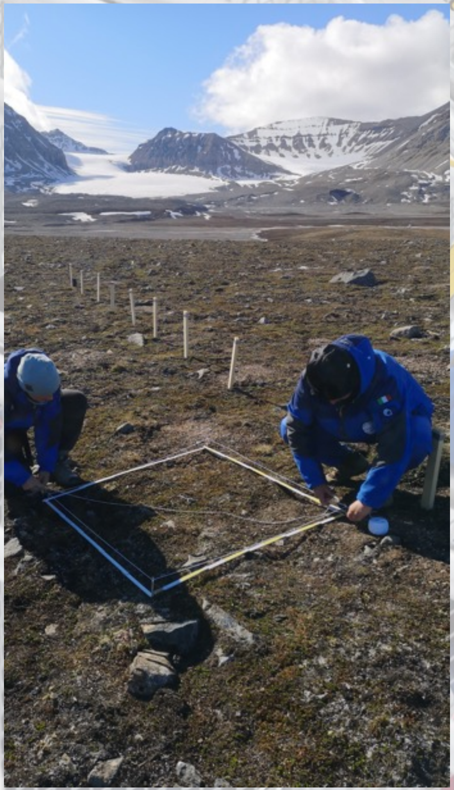
Lack of measurements [Natali 2019]

Winter processes are poorly understood

The amplified warming of the Arctic is **strongest in winter**
but most studies focus on the summer season [Arndt 2020, Jansson and Taş, 2014]

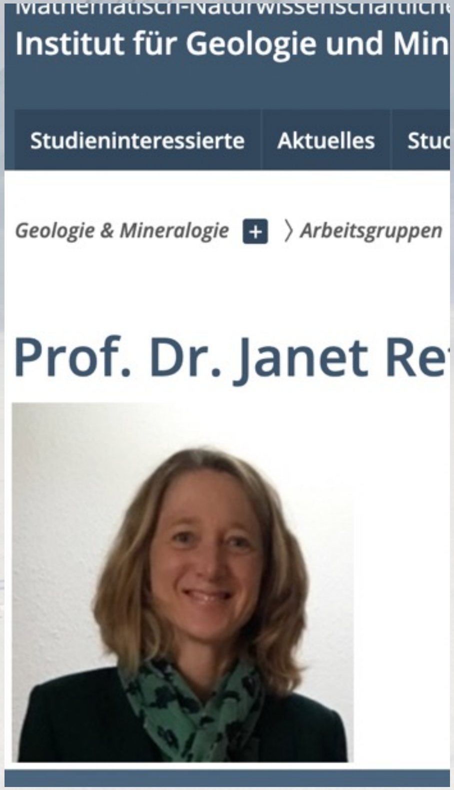
Winter CO_2 flux dynamics is the great unknown in the annual Arctic carbon budget

We rely on…
1) Our existing observatory

We rely on…
2) Our partnership

CNR- IGG (IT)



UNINA-DB (IT)

QMUL (UK)

UoC (DE)

AWI (DE)

PROJECT AIM AND ACTIONS

AIM

Fill the knowledge gap on winter CO_2 fluxes in Svalbard and investigate the drivers

ACTION PLAN

Start: SUMMER 2023

Installing a new station for winter monitoring of CO_2 fluxes and **microbiological activity** @ the CZ observatory in the Bayelva basin near Ny Ålesund, Svalbard

Year 1

Implementing a **data service** (CNR NyA Carbon Flux Observatory)

Investigating **microbial processes** in winter soil

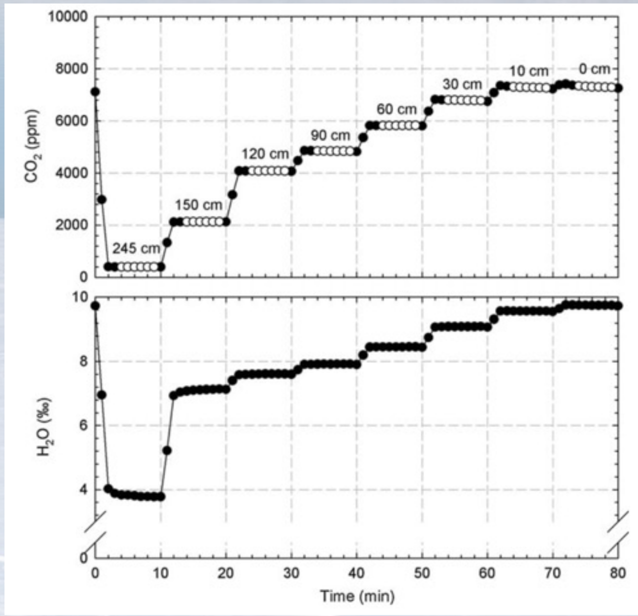
Year 2

Developing data-driven and process-based **models**

What CO_2 winter fluxes have been measured by similar experiments?

	Minimum value micromol/m2/sec	Maximum value micromol/m2/sec
ER Diffusion Winter (*)	0.043	0.071
ER trace-gas Winter (*)	0.005	0.080
ER Eddy Covariance -NYA Winter (°)	0.000	0.500
ER Flux chamber-NYA Summer (°)	0.125	4.043

	min ratio	max ratio
ER summer / ER winter	3	60



DOI 10.1007/s10533-009-9302-3

ER = Ecosystem Respiration

(*) DOI: 10.1029/2009GB003667
(°) CNR CZ Obs
All measures in Svalbard

Challenge # 1

The instrumentation must resist the Arctic winter AND have a high sensitivity

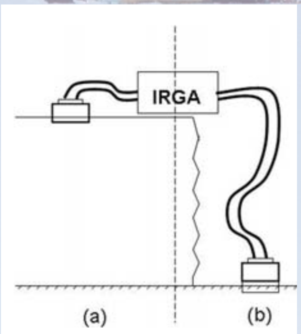
HOW TO MEASURE WINTER CO_2 FLUX FROM THE SNOWPACK

Examples from the literature

At the bottom of a snowpit

”direct methods”
Using flux chambers

at top and bottom of a snowpit



Measuring the diffusion through the snowpack

$$F_{CO_2} = -D_{CO_2}\left(\frac{\partial C_{CO_2}}{\partial z}\right)$$

Several instrumental set-ups

HOW TO MEASURE WINTER CO_2 FLUX FROM THE SNOWPACK

From: Björkman et al, 2010 - doi:10.1029/2009GB003667

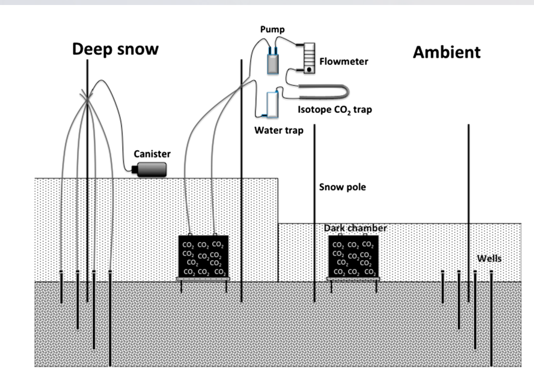
"…..These differences result not only from using contrasting methods but also ***from the differences in the assumptions within the methods*** *when quantifying CO2 production and effluxes to the atmosphere. Because snow can act as a barrier to CO2, Fsoil is assumed to measure soil production, whereas* ***FSF6, Fsnow, and F2-point are considered better approaches*** *for quantifying exchange processes between the soil, snow, and the atmosphere. This study indicates that* ***estimates of winter CO2 emissions may vary more as a result of the method used than as a result of the actual variation in soil CO2 production*** *or release. This is a major concern, especially when CO2 efflux data are used in climate models or in carbon budget calculations, thus highlighting the need for further* ***development and validation of accurate and appropriate techniques****."*

HOW TO MEASURE WINTER CO2 FLUX FROM THE SNOWPACK: the Fick's law approach

Examples from the literature

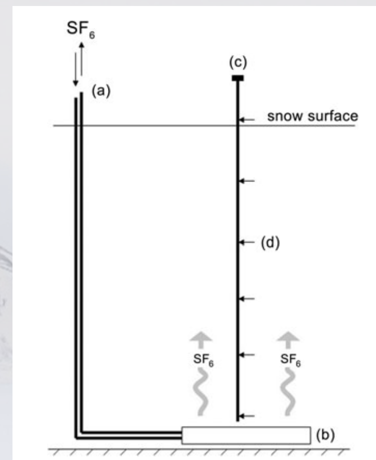
$$F_{CO_2} = -D_{CO_2}\left(\frac{\partial C_{CO_2}}{\partial z}\right)$$

At the bottom of the snowpack
And in open air



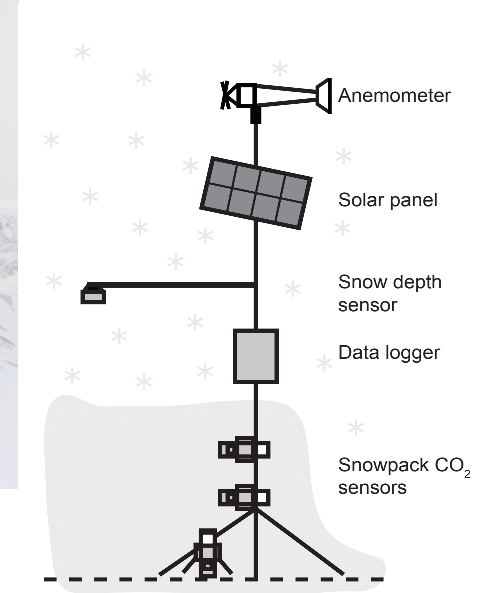
Lupascu et al. 2018
10.1029/2018JG004396

Through the snowpack
with reference gas SF_6



Björkman et al., 2010
10.1111/j.1751-8369.2010.00150.x

Measuring the diffusion through the snowpack with Vaisala or LI-COR



Seok et al 2009
10.1007/s10533-009-9302-3
Graham 2018
10.5194/bg-15-847-2018

INSTRUMENTATION for CO_2 flux MEASURES THROUGH THE SNOWPACK

CO_2 flux from the snowpack is measured using the diffusion Fick's law

A tower where CO_2 concentration in snow is measured at 7 different heights inside the snowpack

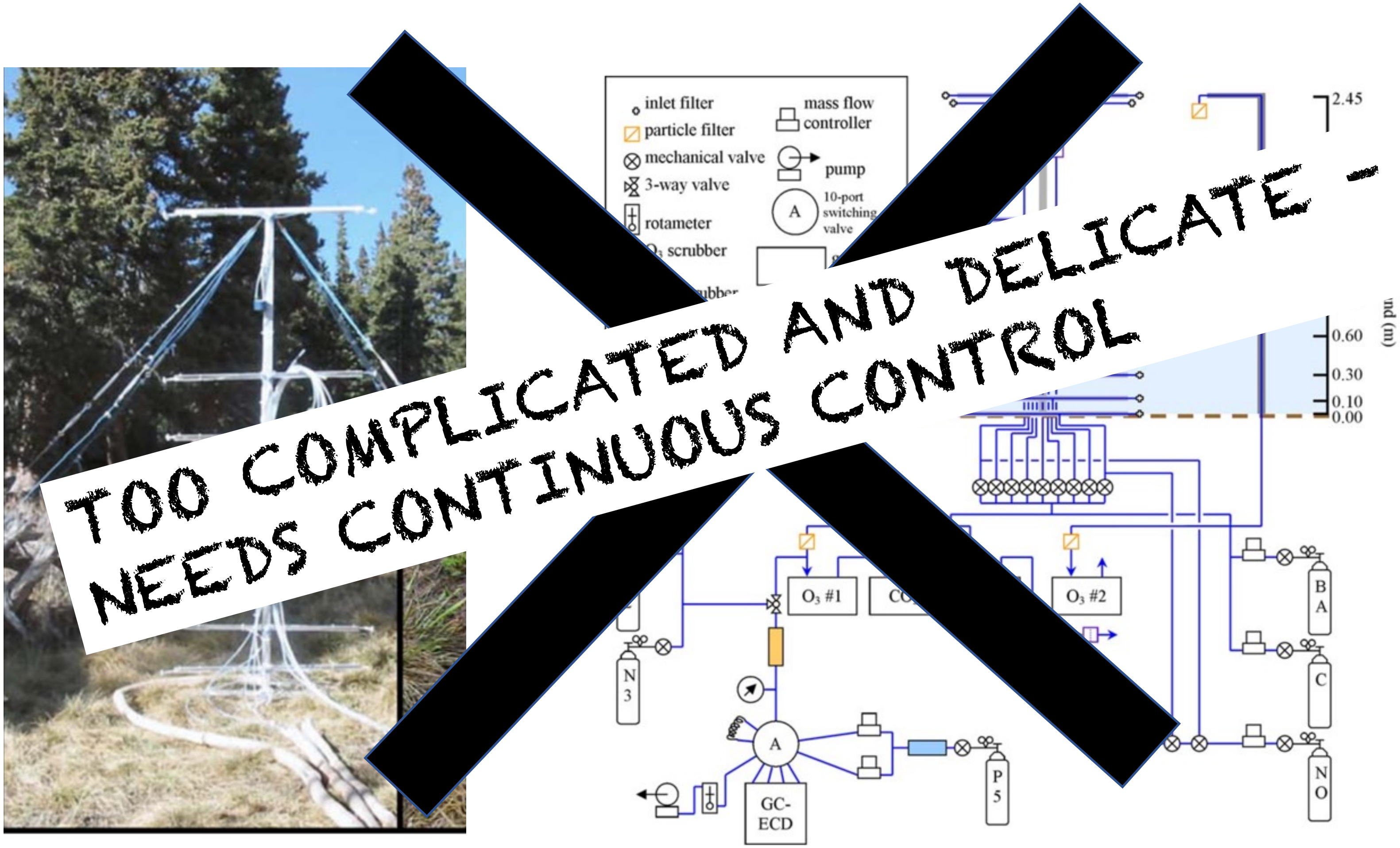
CO_2 concentration is measured via a **LI-COR 7000 IRGA** placed in an underground laboratory

A switcher alternates the sampling points - complete cycle takes 80 min; 18 cycles per day.

The sampling manifold, calibration system, **and data acquisition are controlled through an array of digital input/ output modules**, temperature input components, and LabVIEW software

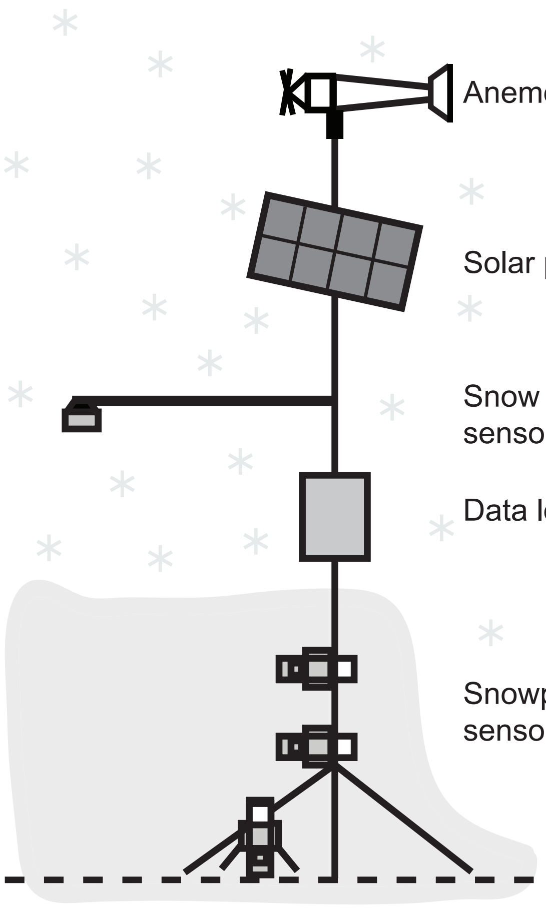
From Seok, Biogeochemistry (2009) 95:95–113 DOI 10.1007/s10533-009-9302-3

INSTRUMENTATION for CO_2 flux MEASURES THROUGH THE SNOWPACK



From Seok, Biogeochemistry (2009) 95:95–113 DOI 10.1007/s10533-009-9302-3

INSTRUMENTATION for CO_2 flux MEASURES THROUGH THE SNOWPACK



CO_2 flux is measured using the diffusion Fick's law

Tower: CO_2 concentration in snow is measured at 4 different heights inside the snowpack + 5 cm in the soil + in ambient air

CO_2 sensor: **Vaisala CARBOCAP®** Carbon Dioxide Probe

Datalogger: Campbell Scientific

Data are collected at the end of the season
Low maintenance needed - the system can be left unattended – no piping and no risk of clogging

L. Graham and D. Risk, Biogeosciences, 2018 https://doi.org/10.5194/bg-15-847-2018

CHOSEN MEASUREMENT METHOD for CO_2 FLUX FROM THE SNOW PACK

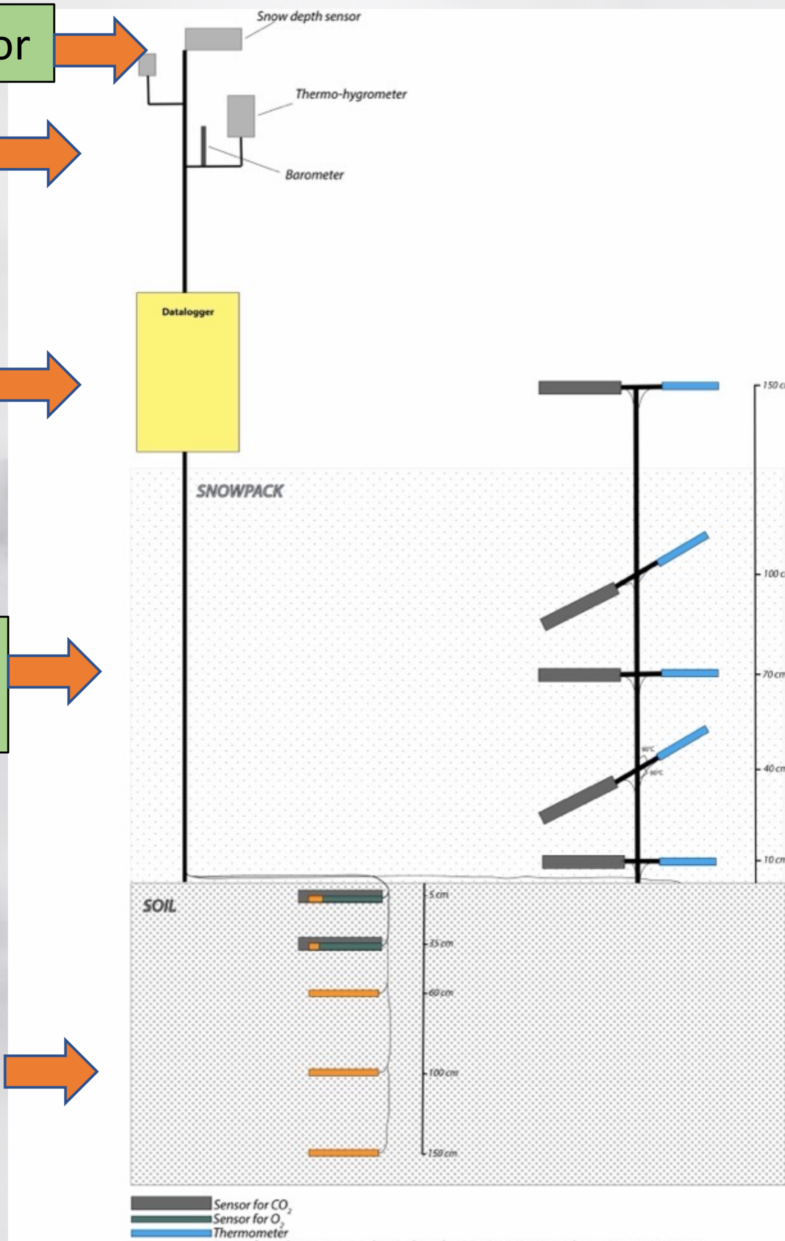
Snow depth sensor

Meteo station

datalogger

5 CO_2 and AirT sensors

Soil sensors
T, VWC, O_2, CO_2



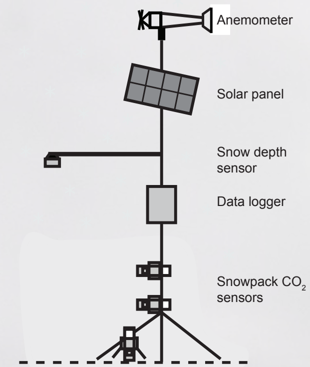


Figure 1. Schematic of initial (2014) CO_2 monitoring stations (NM1, NM2) at North Mountain, Cape Breton. Snowpack CO_2 sensors were at 0, 50, and 125 cm within the snowpack (diagram not to scale).

From: *Explaining CO2 fluctuations observed in snowpacks*
Laura Graham and David Ris
Biogeosciences, 15, 847–859, 2018
https://doi.org/10.5194/bg-15-847-2018

$$F_{CO_2} = -D_{CO_2}\left(\frac{\partial C_{CO_2}}{\partial z}\right)$$

Data needed:

D_{CO2} = Diffusivity of CO2 in snow

Calculated empirically from

- Snowpack porosity
- Snowpack tortuosity
- Diffusion coefficient of CO2

Challenge # 2

Minimising propagation of errors in applying Fick's law

Sources of error in CO_2 flux measurements

Question: in-field measured parameters errors effects on CO_2 flux?

$$F_{CO_2} = -D_{CO_2}\left(\frac{\partial C_{CO_2}}{\partial z}\right)$$

Data needed:

D_{CO_2} = Diffusivity of CO_2 in snow + dCO_2/dz

D_{CO_2} = Calculated empirically from:

- Snowpack porosity
- Snowpack tortuosity

} **calculated from snow density**

- Diffusion coefficient of CO_2

dCO_2/dz = > $\Delta CO_2/\Delta z$ in max **4 intervals** when the instruments all all covered with snow

Challenge # 3

Understanding microbiological functions in Arctic winter soil

Major challenges in

understanding the biogeochemical functions of the Arctic microbial communities

- ***WHO IS THERE?*** Assuring that we properly detect the seasonal changes in the microbial community composition through a **sufficient number of time and space replicates**

- ***WHAT CAN THEY DO?*** Understanding the biogeochemically-relevant functions through metagenomic sequencing

- ***WHAT ARE THEY DOING?*** In situ- measurements of extracellular enzymatic activities will let us know what metabolic functions are active in the Arctic winter soil

Challenge # 4

Selecting and estimating the process based models equations and <u>parameters</u>

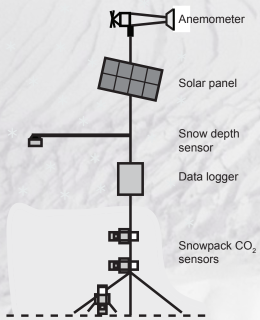
Modelling - From the proposal:

"The collected data……will be used to ***develop a suite of models*** *to explicitly simulate winter and year-round soil processes and enable the forecasting of biological and physical changes due to climate forcing, thanks to the modelling expertise of the proponents. Such models…..could be used as stand-alone, or* ***inserted as modules in local/regional atmospheric models,*** *providing the lower boundary conditions at soil/snow/vegetation interface".*

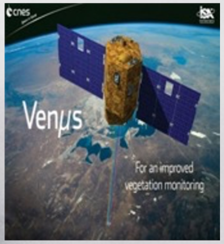
The Carbon integrated observatory

Data available through SIOS and CNR Virtual Research Environments

CO2 fluxes from snowpack

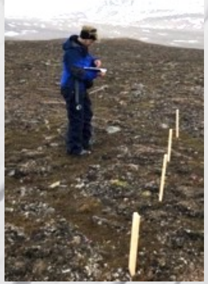


Satellite-based monitoring of the tundra vegetation



Eddy covariance measuring of CO_2 fluxes

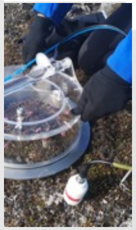
Measuring the active layer depth and snow height

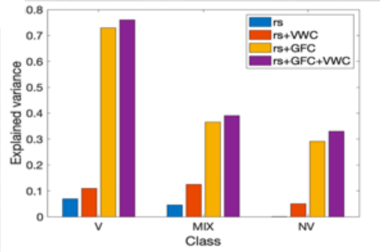


Modelling CO_2 fluxes drivers

$$GPP = \frac{F\,\alpha_0\,rs}{F + \alpha_0\,rs}(A_0 + A_1 GFC + A_2 VWC)$$

$$ER = (a_0 + a_1 GFC + a_2 VWC)\exp{(b_0 T_a)}$$






....Thanks a lot!