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IMPACT OF ARCTIC SHRUB EXPANSION ON THE SUMMER THERMAL REGIME OF PERMAFROST

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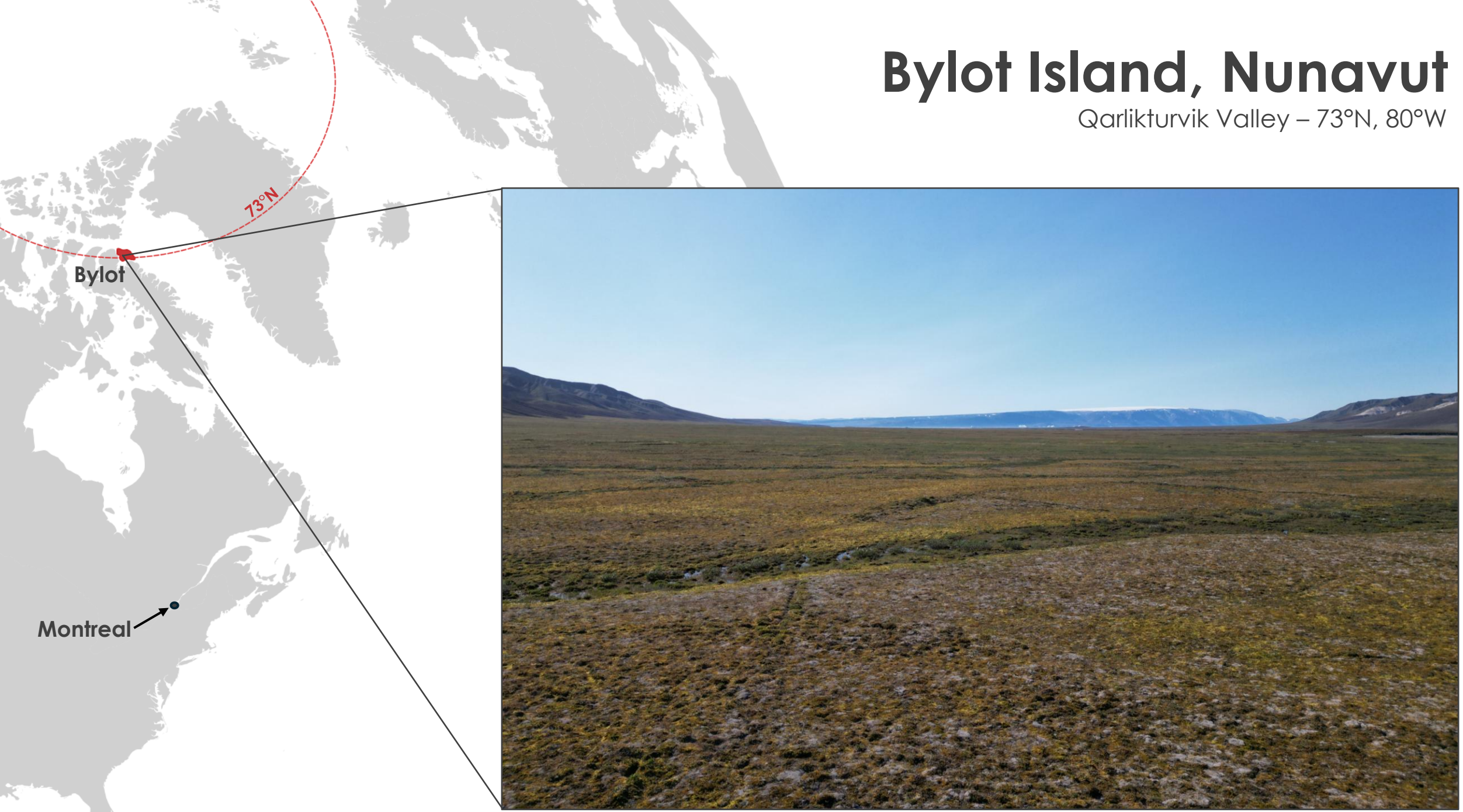
Laboratoire d'hydrologie des régions froides

Bylot Island, Nunavut

Qarlikturvik Valley – CEN research station

Bylot Island, Nunavut

Qarlikturvik Valley – 73°N, 80°W



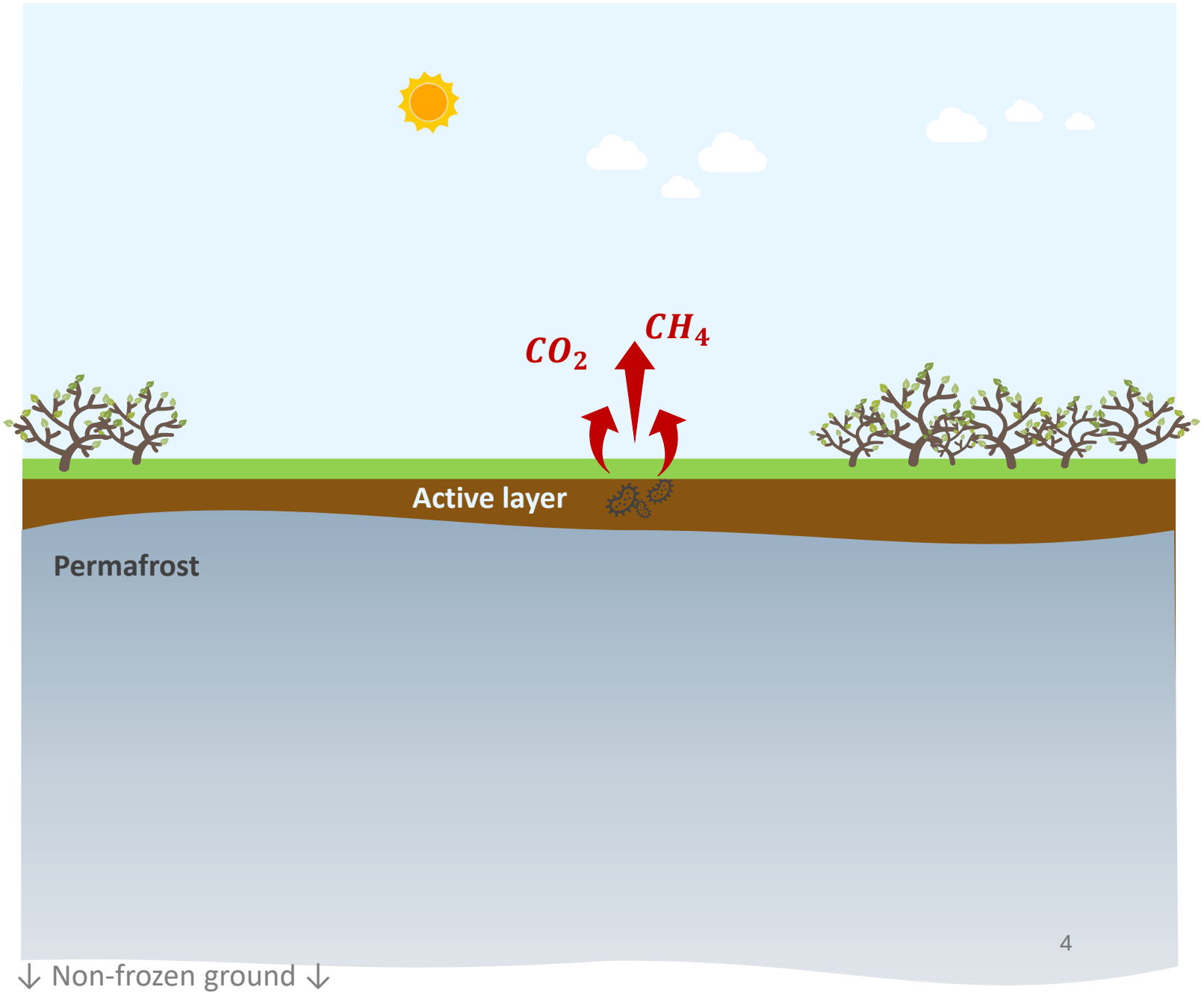
Why Study Permafrost?

The **active layer** is the top soil layer that thaws every year

With thaw, the stored carbon becomes available for decomposition, leading to **greenhouse gases emissions** *(Voigt et al., 2017; PNAS)*

It is estimated to store **twice as much** carbon as the atmosphere *(Schuur et al., 2008, BioScience)*

Crucial to understand how permafrost will evolve with climate change



Arctic Greening and Shrub Expansion

Climate change induced **shrub expansion** has been observed accross Arctic tundra *(Myers-Smith et al. 2011, ERL)*

Shrubs have **complex effects** impacting near surface and ground temperatures *(Bonfils et al. 2012, ERL ; Kropp et al. 2021, ERL)*

Studies have put forward different processes :

Observations say there is a **soil cooling effect** due to shading *(Blok et al., 2010, GCB ; Juszak et al., 2016, EGU)*

Others show through modeling a **local air warming** due to reduced albedo and increased heat transfer to atmosphere *(Beringer et al., 2005, AgrForMet ; Dominé et al., 2016, EGU; Oehri et al., 2022, Nature)*

Very few direct measurements to confirm modeling *(Lafleur & Humphreys, 2018, ERL)*

The processes controlling permafrost thaw under shrubs during summer are not well understood

(Sturm, Racine & Tape 2001, Nature)

Salix richardsonii shrubs on Bylot island - 2024

Surface Energy Budget

Balance of the energy exchanges at the Earth's surface
(1D – surface layer)

$$R_n = H + LE + G$$

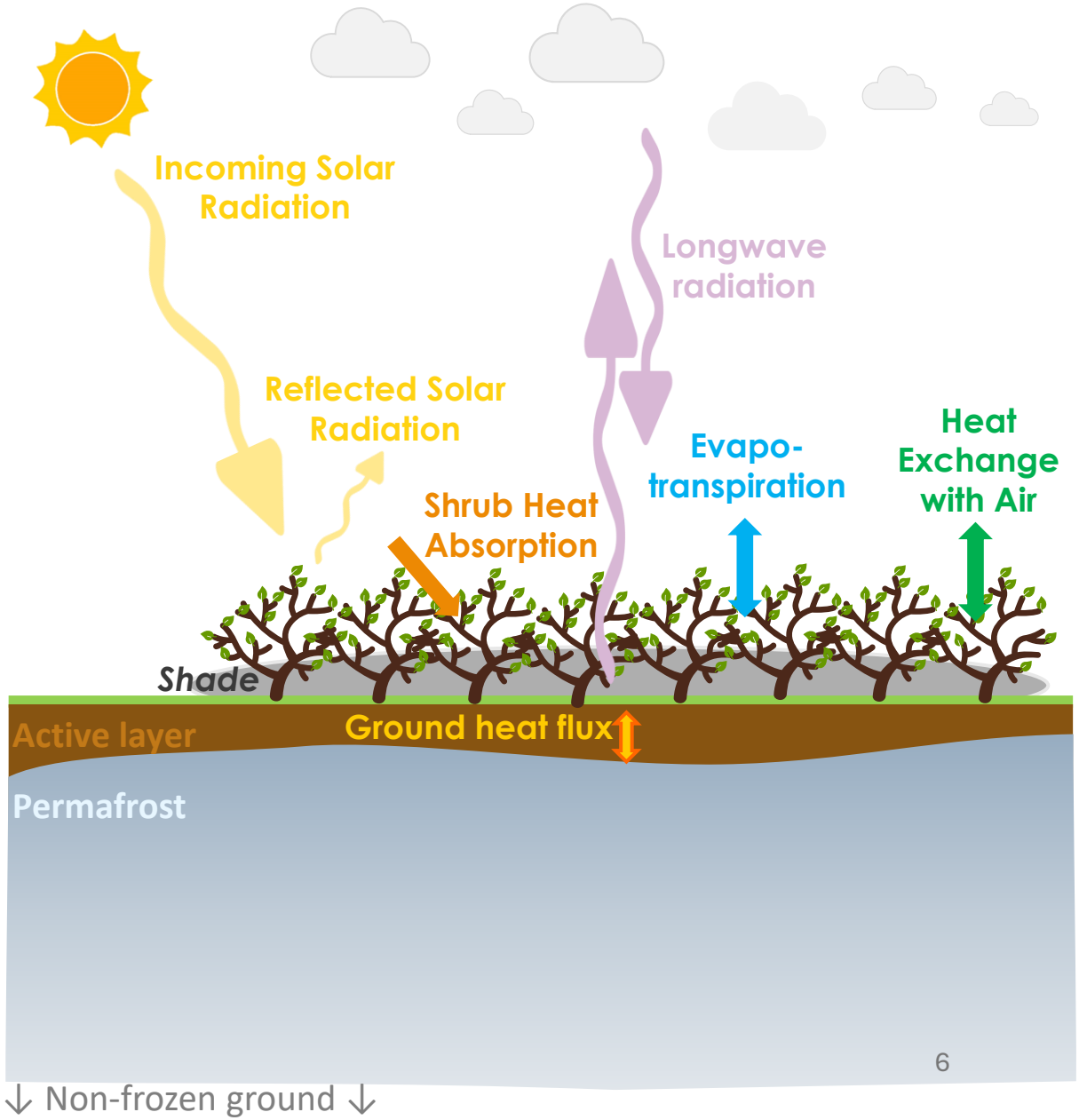
R_n: Net radiation at the surface (shortwave + longwave)

H: Sensible heat flux (transfer of heat due to differences in temperature)

LE: Latent heat flux (transfer of heat due to phase change of water)

G: Ground heat flux (transfer/storage of heat in the soil layer)

Objective : Quantify each term of the energy balance to identify the main processes controlling permafrost thaw in the summer



Energy Budget Quantification

General approach

Net radiation R_n $\quad R_n = SW_\downarrow - SW_\uparrow + LW_\downarrow - LW_\uparrow$

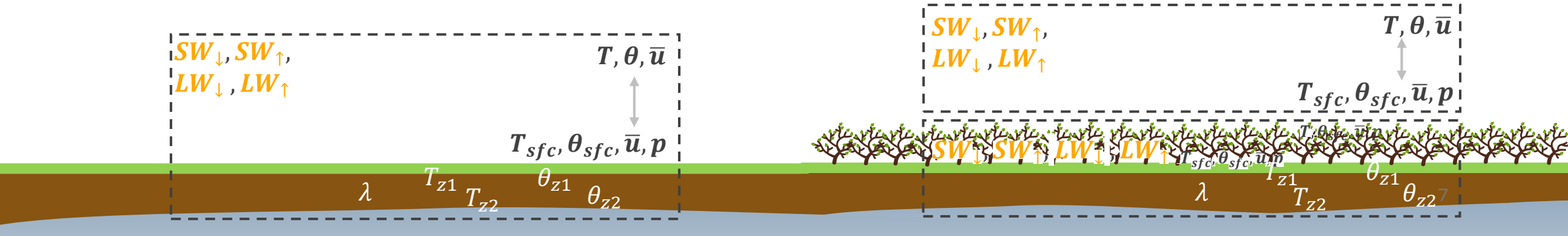
Ground heat flux G $\quad G = -\lambda \frac{\Delta T}{\Delta z} + S$

Sensible heat flux H

Latent heat flux LE

Turbulent flux estimation with **Bulk transfer approach**

- Surface temperature T_{sfc}
- Air temperature T
- Atmospheric pressure p
- Relative humidity θ
- Wind speed $\bar{u}$

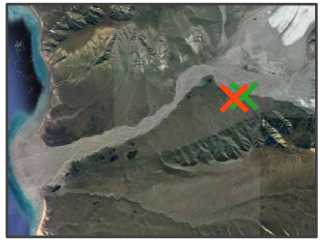


Site intrumentation

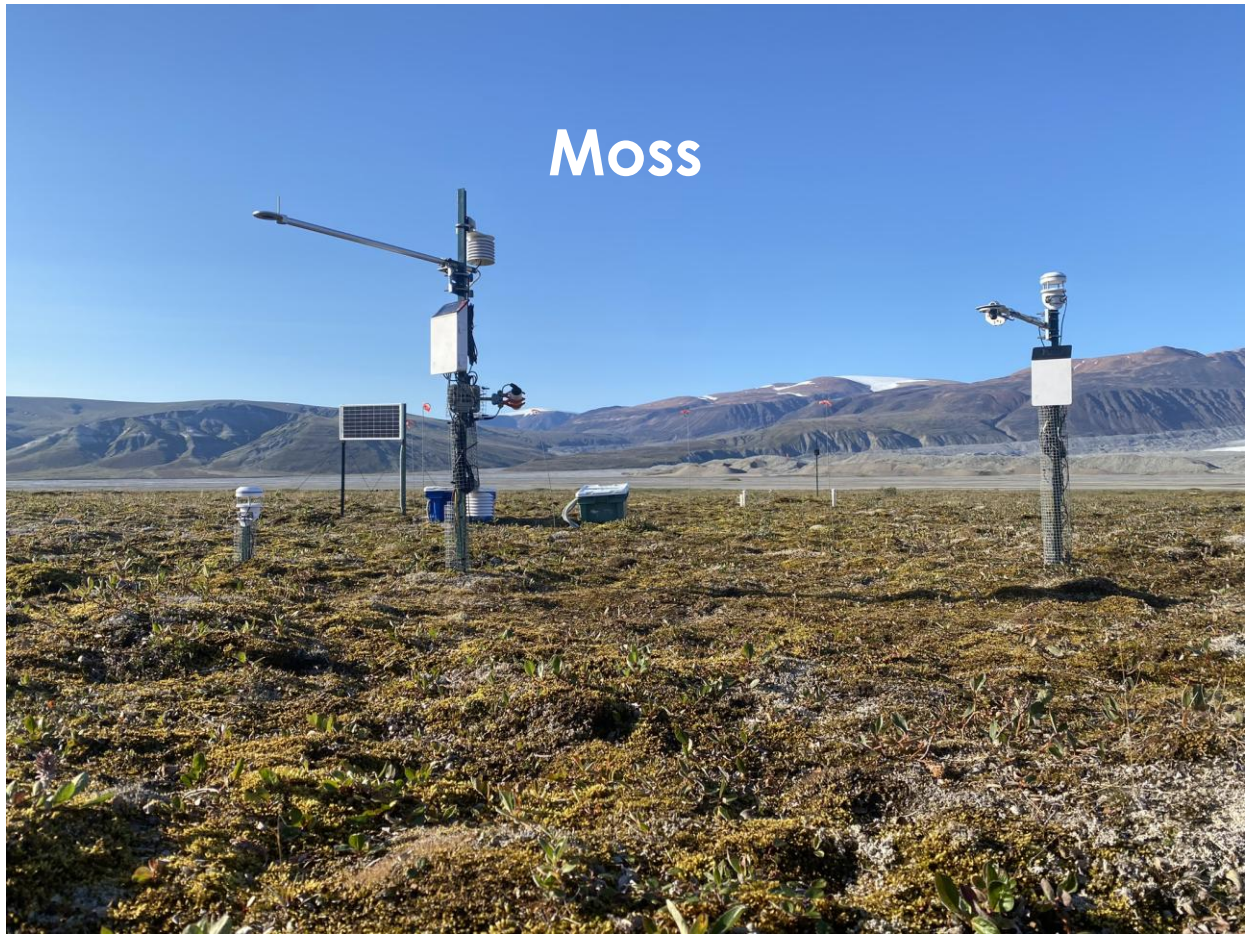
Fly camp close to shrub and moss sites – with Antoine Thiboult

Instrumentation Setup

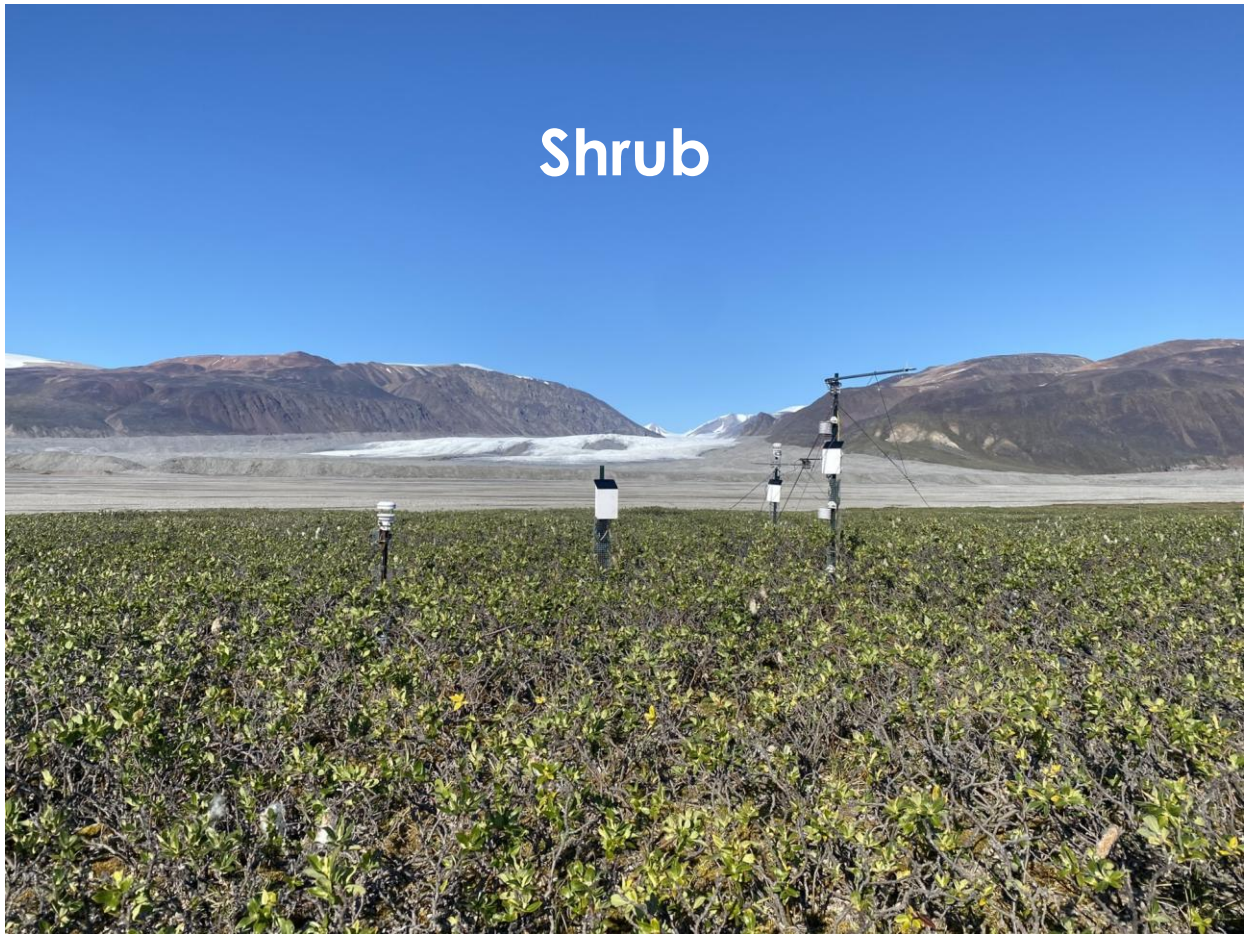
Installation in July 2024



General site localisation



Non-erect vegetation dominated by moss | Active layer ≈ 20cm



Shrub dominated site ≈ 50 cm height | Active layer ≈ 40 cm
Growing season : June – August

Sensors installed

4 components radiometer

Sonic anemometer

Net radiometer


Soil temperature & humidity sensors

Heat flux plates


Snow/soil thermal conductivity

- **Air temperature and humidity**
- **Wind speed and direction**
- **Longwave & shortwave radiation ↓ & ↑**
- **Soil and snow temperature, humidity and thermal conductivity**
- **Soil temperature, humidity and water potential**

Data collection

On site characterization

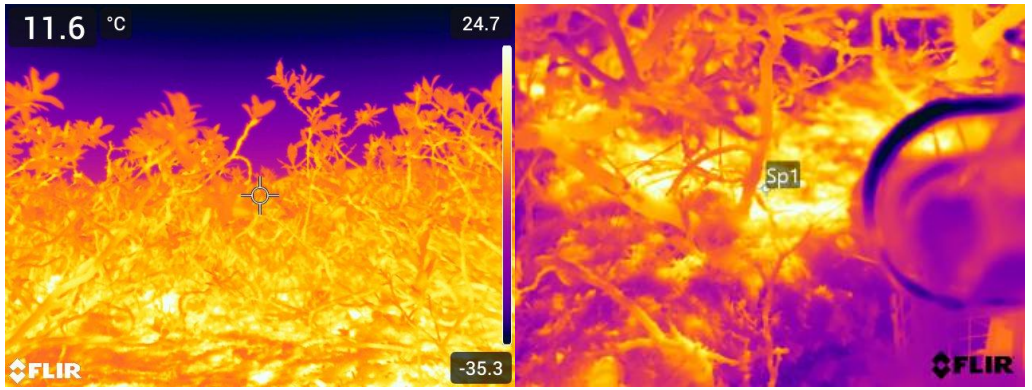
Data collection from August 2024 to August 2025

Quantification of energy budget terms

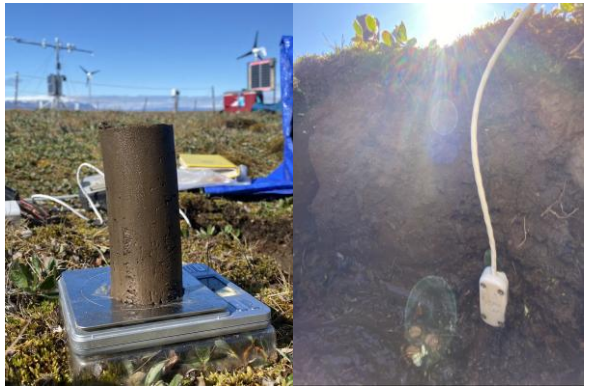
Comparisons with simulations with CLASSIC surface model

Goal is to understand which processes rule permafrost thaw

Shrub LAI/PAI measurements



Themal imagery



Soil thermal properties

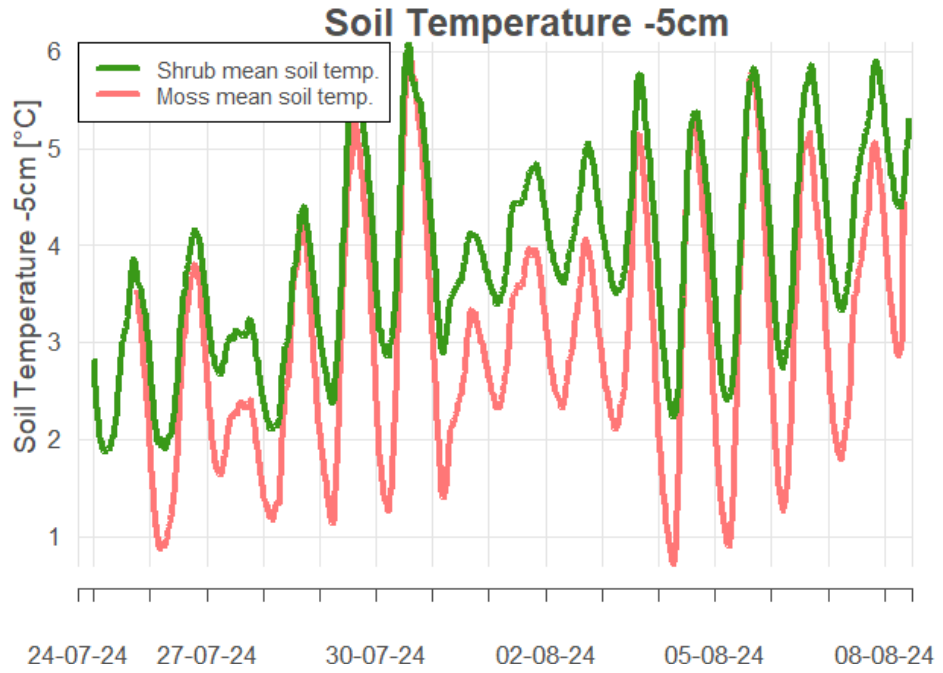
First observations from 2024 field data

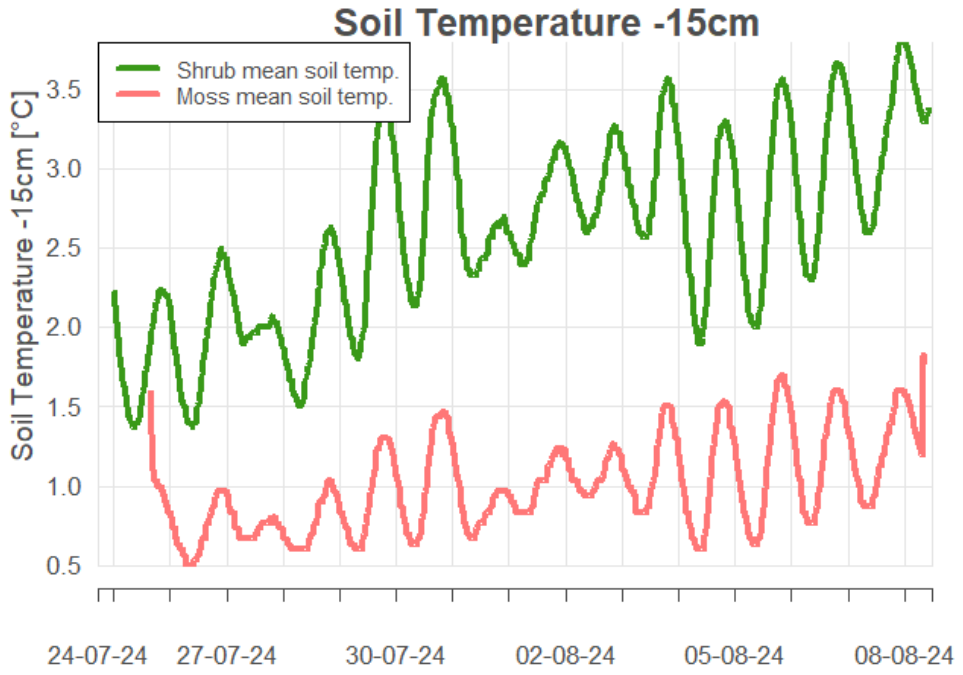
Soil temperatures

Moss site

Shrub site

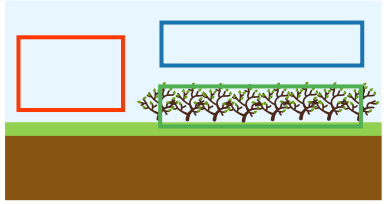
- Soil temperature was measured at -5 cm and -15 cm at three locations for each environment
- Shrub soil generally has higher temperatures, especially at -15 cm





First observations from 2024 field data

Radiative fluxes



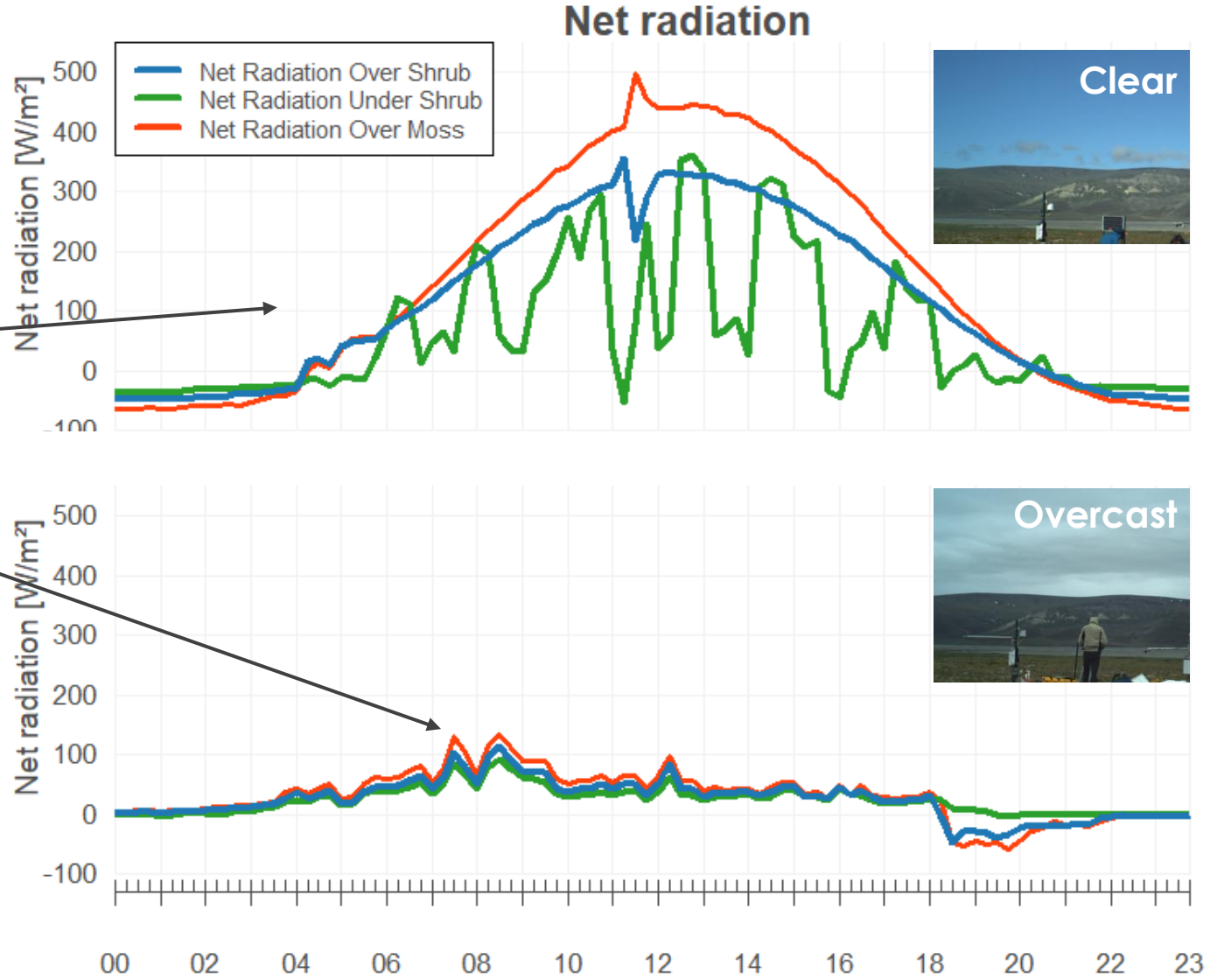
$$R_n = H + LE + G$$

Highly dependent on cloud conditions

Variable net radiation under shrubs *(green line)*

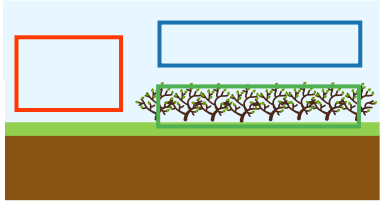
Overcast days = smaller difference

Lower net radiation under shrubs



First observations from 2024 field data

Air temperature and wind speed



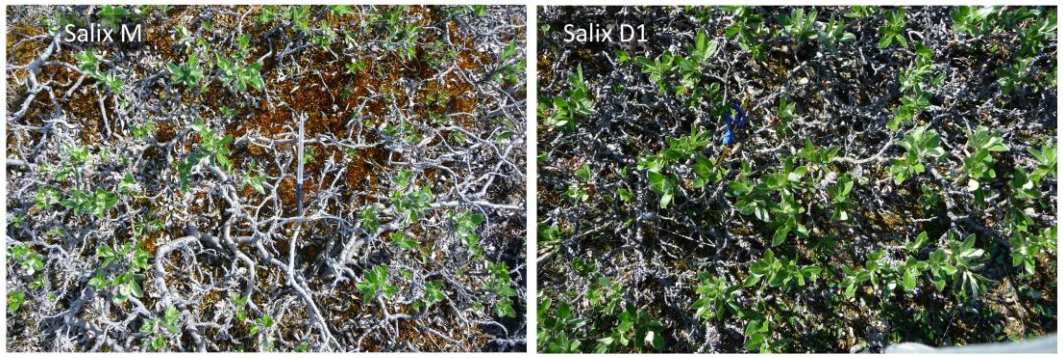
$$R_n = H + LE + G$$

Warmer air temperature under shrubs during the day

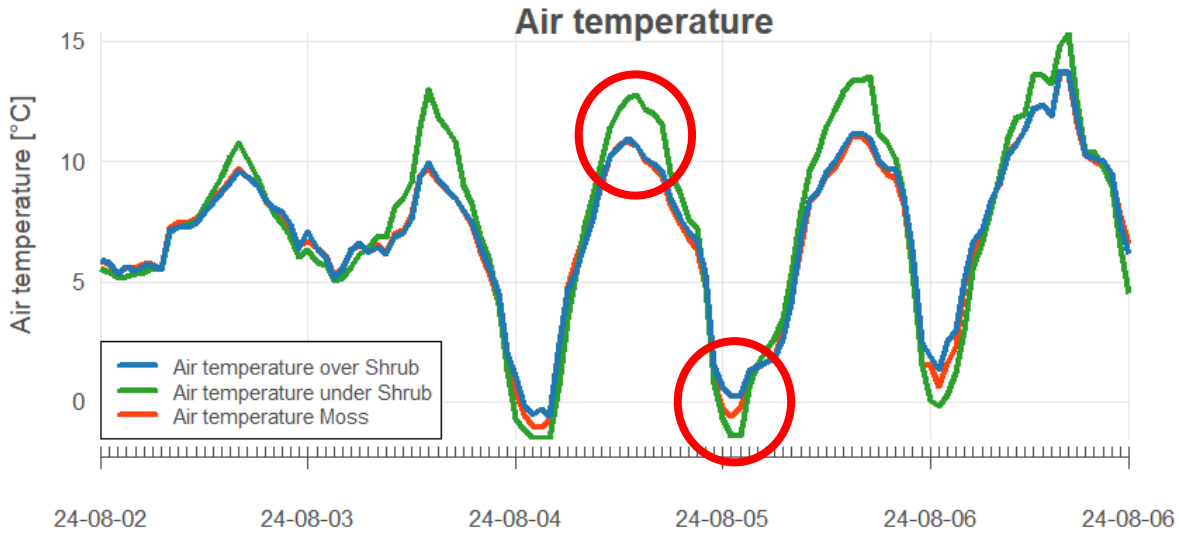
Colder temperatures under shrubs at night

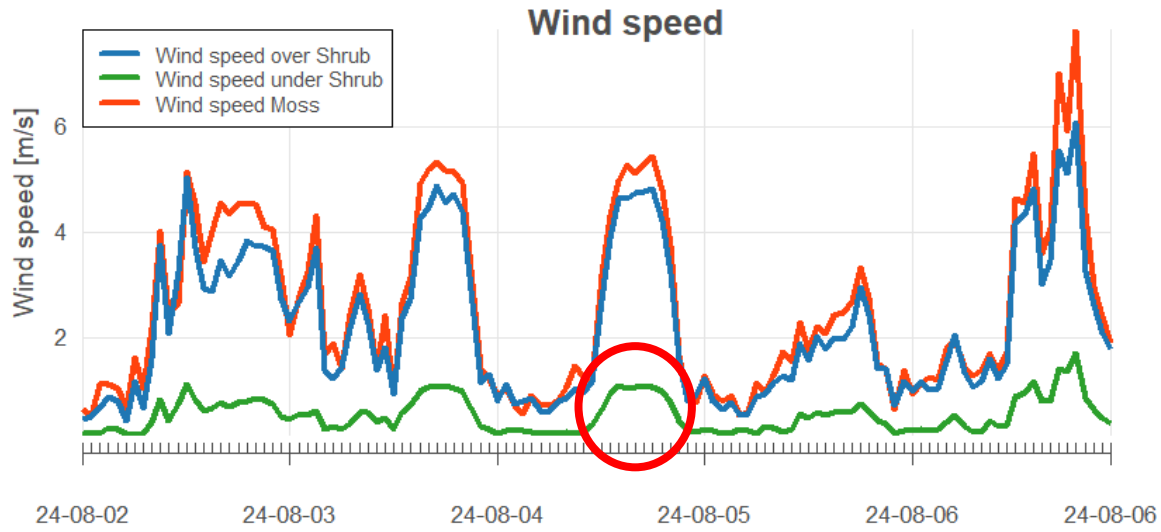
Much lower wind speed under shrubs

- Shrubs act as insulating barrier supressing most of the turbulence
- Could lead to less heat exchanges with atmosphere
- Low branch density could modify expected shrub dynamics



(Bylot shrubs, Florent Dominé)





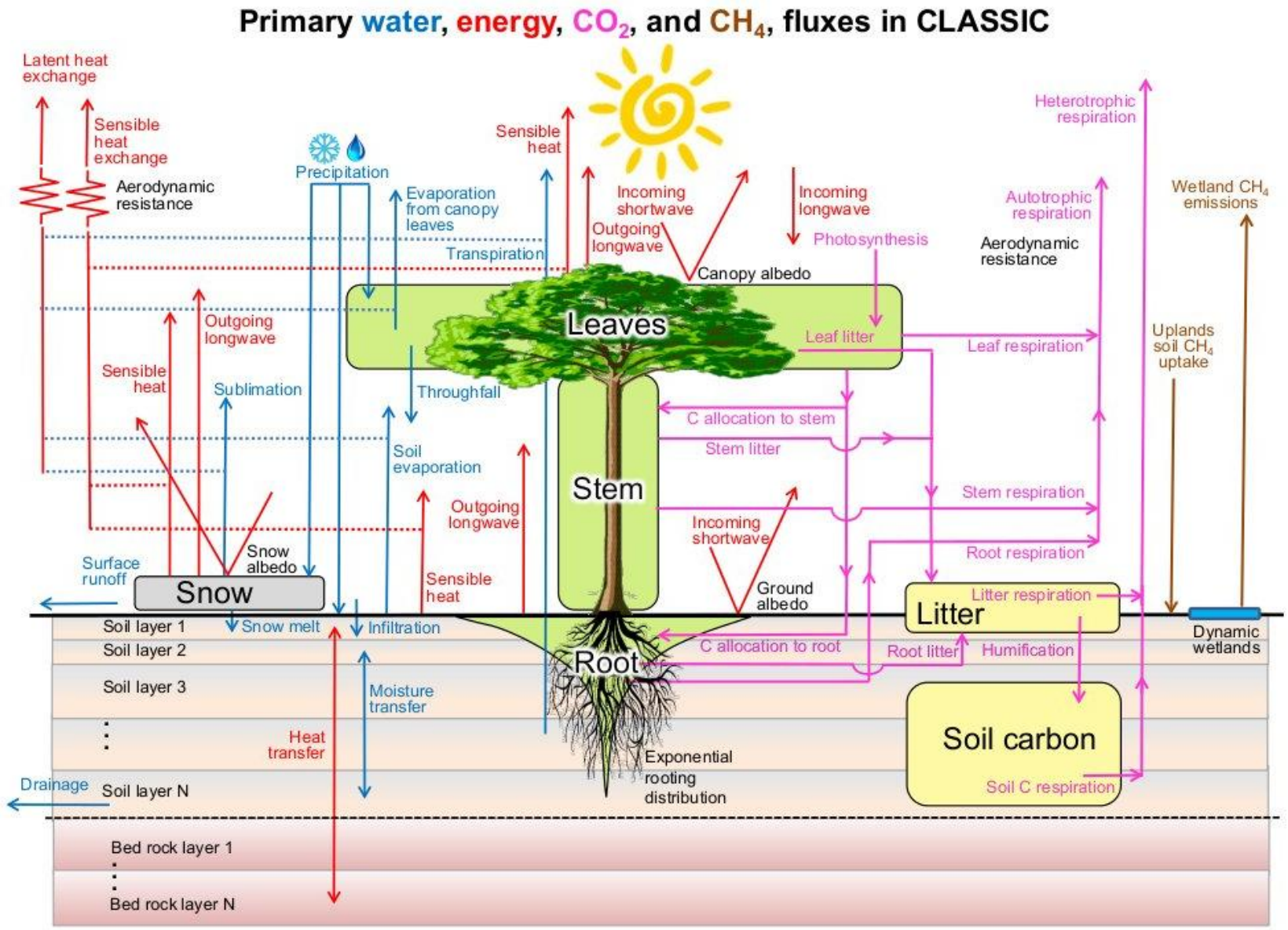
CLASSIC surface model

Developped and used by ECCC

CLASSIC = CLASS + CTEM

Simulates exchanges of energy, water and carbon between ground and atmosphere

Site specific data from Bylot island will be used to parameterize the model and look at longer horizons



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What's next

- Study snow accumulation at each sites (snow pits) – *May 2025*
- Download final data sets (*July 2025*)
- Data correction (humidity and SW radiation)
- Quantify turbulent heat fluxes / Complete SEB
- Compare observations with CLASSIC model
- Share results (*2026*)

Conclusion and Project Relevance

Poorly understood shrub dynamics and their impact on permafrost thaw in the Arctic

Conflicting and complex energy exchange processes

Unique field-based approach in a remote Arctic tundra environment

Comprehensive dataset for climate models validation

Further develop relationships and share knowledge with local community of **Mittimatalik**


Thank you!

For questions and suggestions :

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