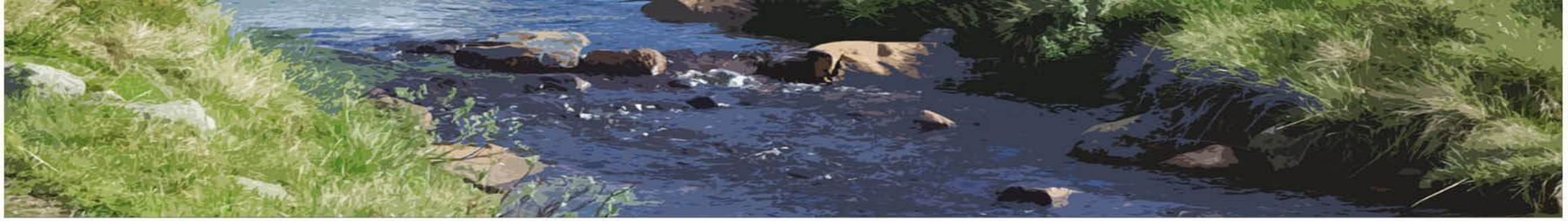

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Implementing moss and lichen and their biophysical impacts in CLM-FATES

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1. *Department of Geosciences, University of Oslo, Norway*
2. *Norwegian Research Centre NORCE and Bjerknes Centre for Climate Research, Norway*
3. *Norwegian Institute for Nature Research*
4. *Natural History Museum, University of Oslo, Norway*

Moss and lichen as unique PFTs

- A “living skin” at the soil surface in many cold and dry environment and early-successional seres.
- Poikilohydric: no actively regulation of their water status, but adapt in a mostly passive way to the water conditions
- High diversity
- Their relevance to land-atmospheric interaction and carbon cycling is still under debate.
- Their response to global changes are also highly uncertain
  - Can cope with a high variety of climatic stresses and success in heavily disturbed areas with human impact
  - Prone to anticipated climate change (warming)

Cladonia stellaris

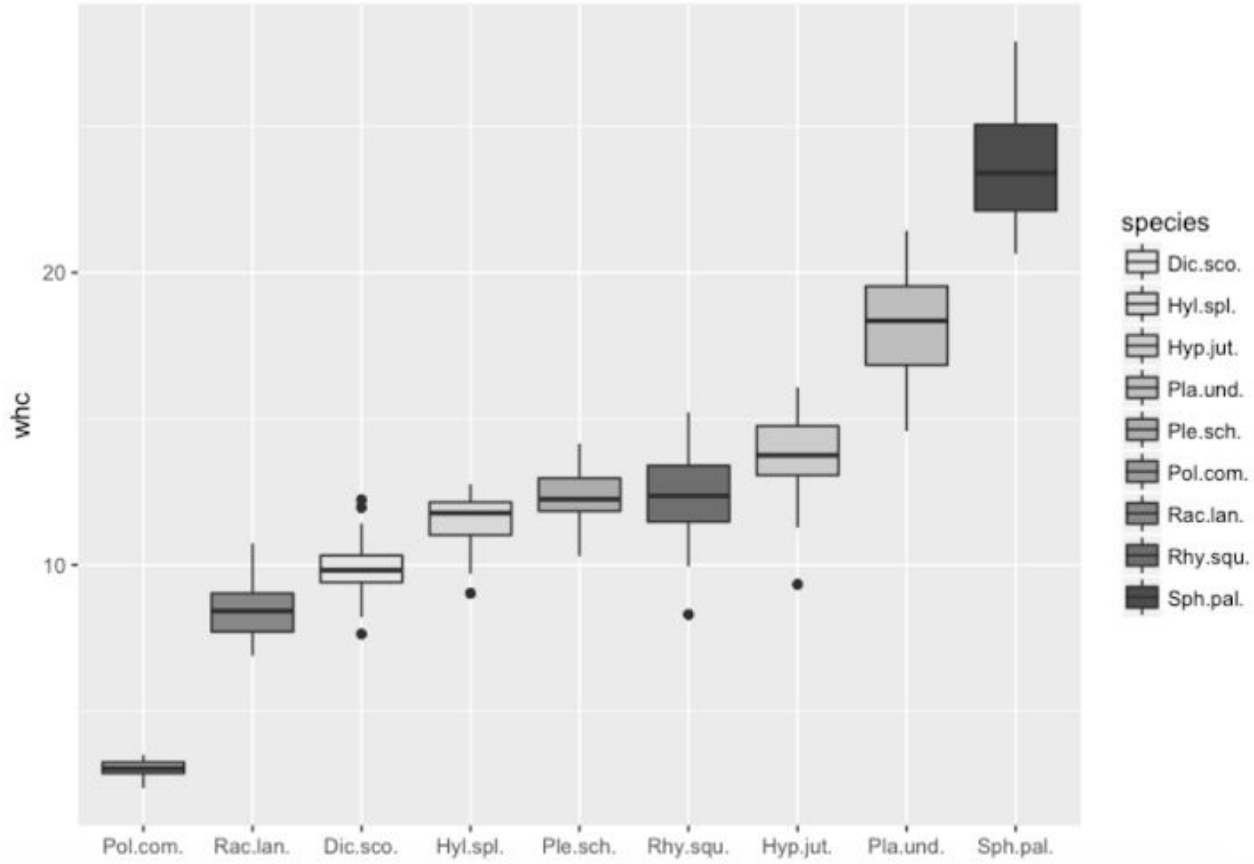
Lichen

Sphagnum

Moss

Unique biophysical impact of moss and lichen

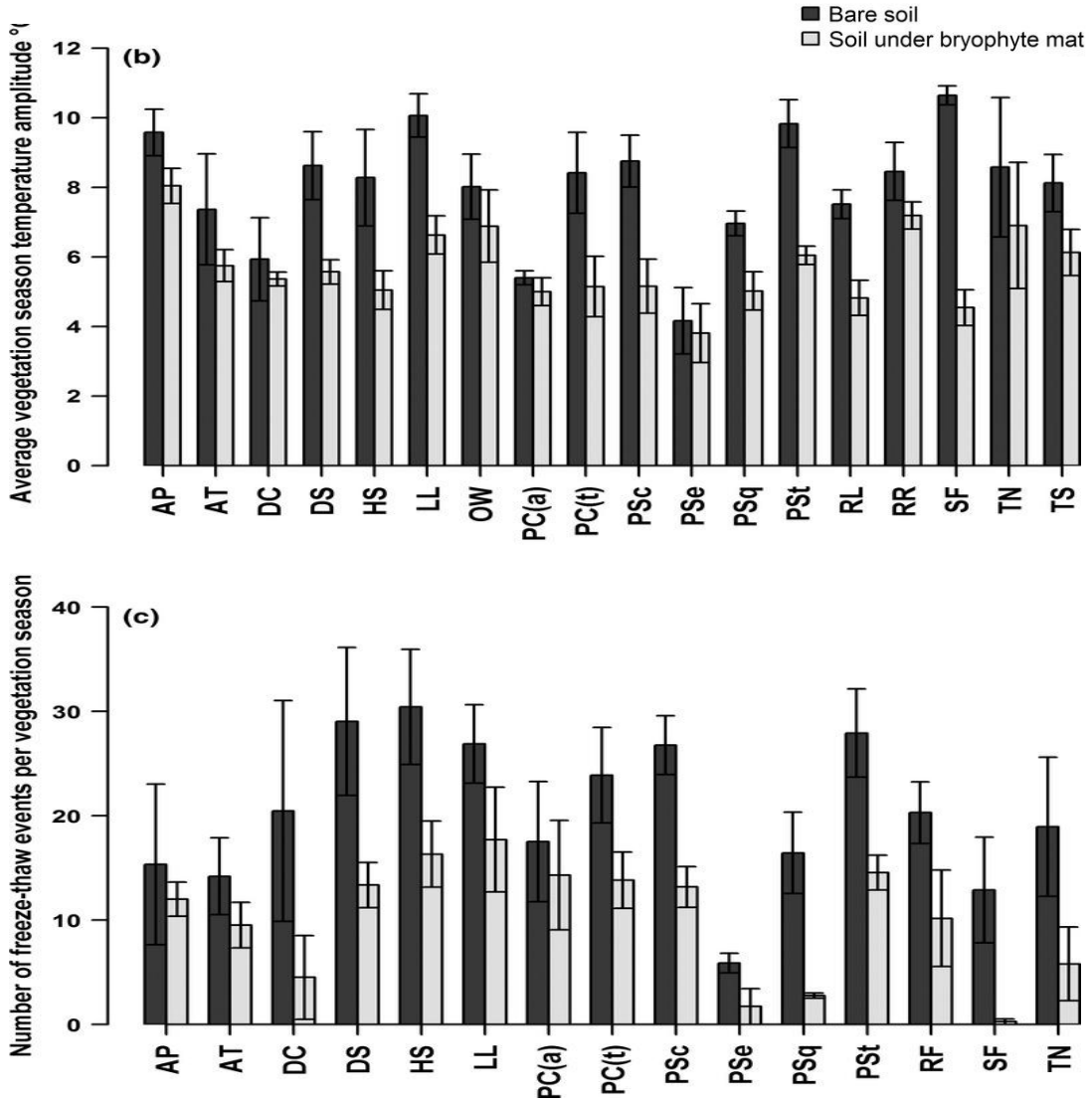
- Water holding capacity



Sara Buscà Riu, Project report, personal communication from Vigdis Vandvik

Unique biophysical impact of moss and lichen

- Water holding capacity
- Thermal Insulation



Soudzilovskaia et al., 2013

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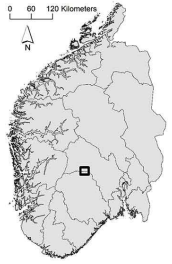
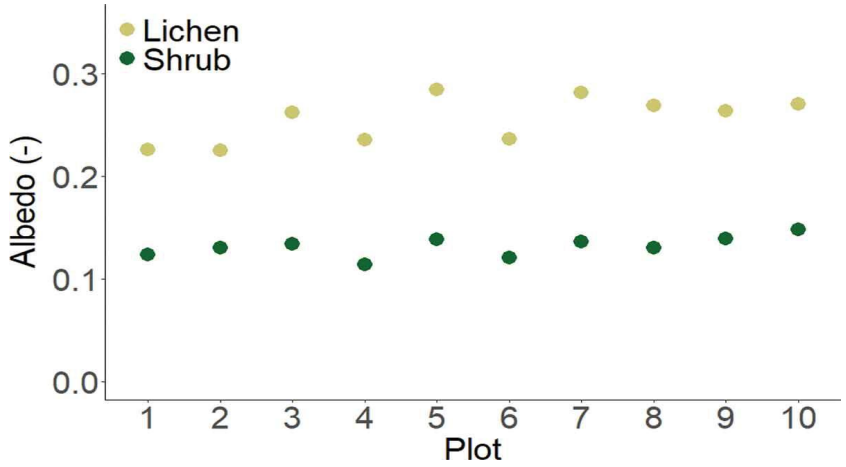
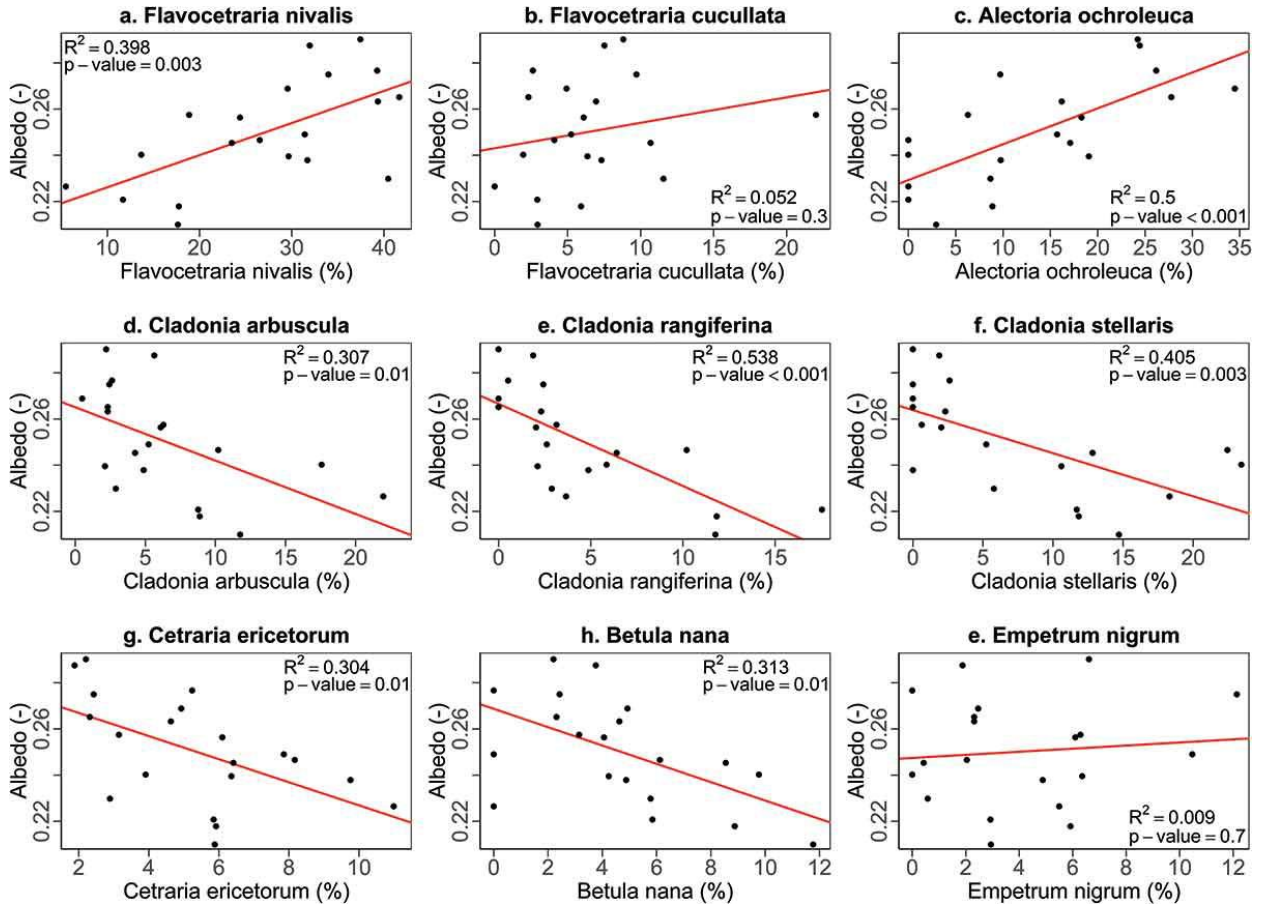
Unique biophysical impact of moss and lichen



- Water holding capacity
- Thermal Insulation
- Albedo





Aartsma et al., Arctic, Antarctic, and Alpine Research, 2020

Unique biophysical impact of moss and lichen

- Water holding capacity
- Thermal Insulation
- Albedo
- Photosynthesis

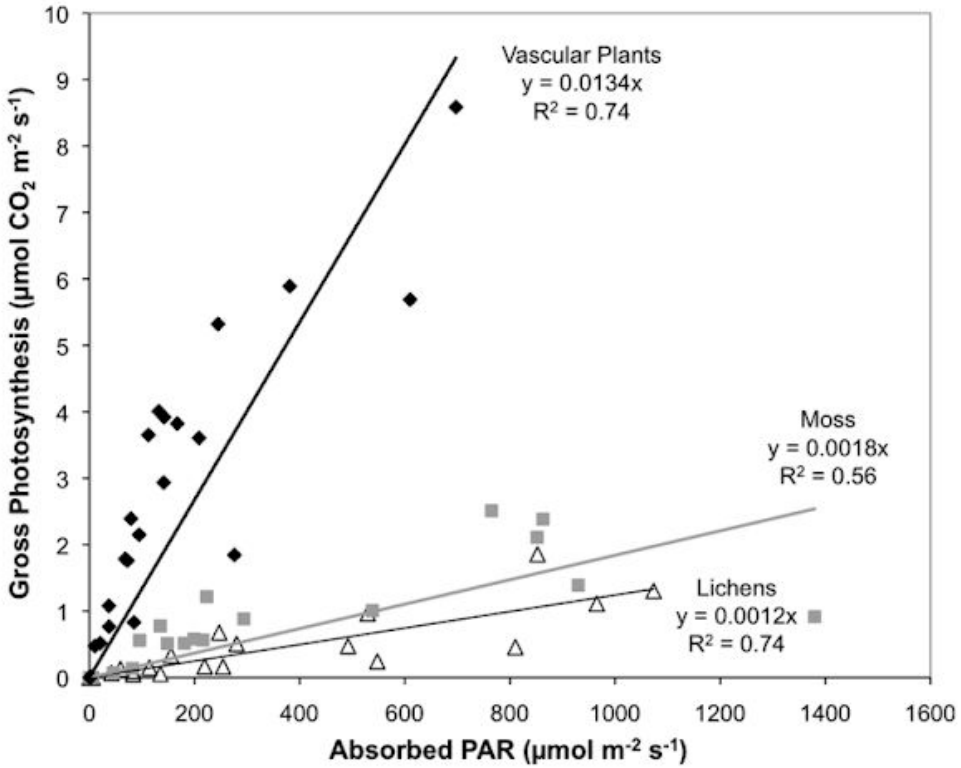


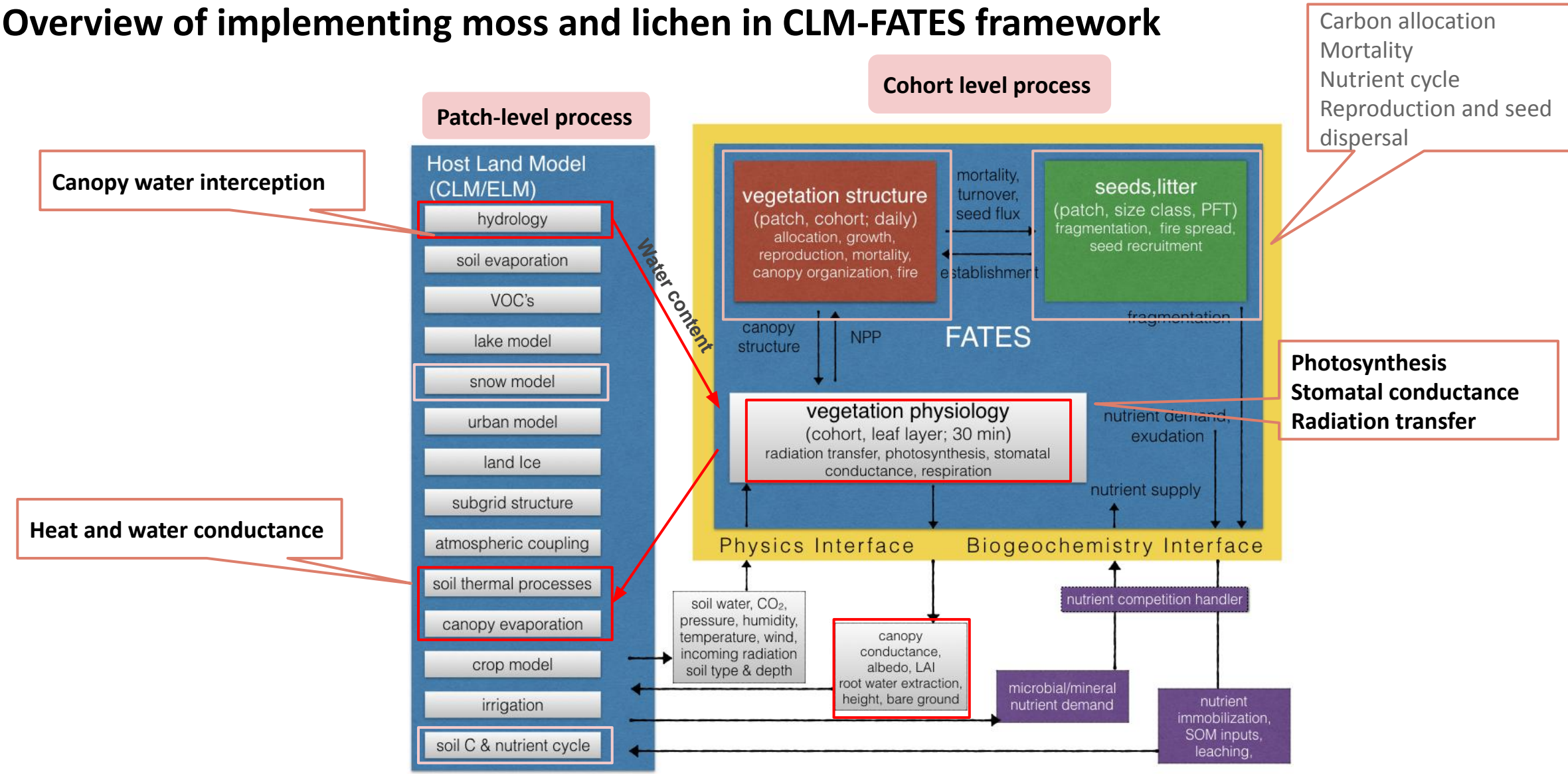
Fig. 1. Absorbed PAR and gross photosynthesis for the three vegetation functional types from plot data collected July 20 and August 5, 2001. Light use efficiency for each functional type was calculated from these data as the slope forced through the origin. See Table I for description of regressions.

Huemmrich et. al. 2013

Previous efforts in modelling the biophysical impact of moss and lichen

	JASBACH (Porada et al. 2013, 2016)	ORCHIDEE (Druel et al. 2017)	JULES (Chadburn et al. 2015)
Heat transfer	Addition layer on top of soil Soil thermal conductivity affected by moisture content	Soil layer Soil thermal conductance affected by biomass/density/moisture	Soil layer Soil thermal conductance affected by soil moisture
Photosynthesis	The CO2 diffusivity decrease with water content Vcmax increase with water content	Stomatal conductance not related to VPD Down regulated by water content (desiccation function)	No
Albedo	fixed value	C3 grass	Soil (likely)
Water storage	Coupled to the plant interception reservoir	Water from soil by assuming a root profile	Water suction and storage similar to soil

Overview of implementing moss and lichen in CLM-FATES framework



Fisher and Koven, Fates Tutorial, 2019

https://github.com/NGEET/fates/issues/707

Implementing moss and lichen in CLM-FATES

- **Changes in parameter and surface data files**
  - e.g., Vcmax25, optical parameters, LAI, SAI, HTOP
- **Canopy water interceptation**
  - Increase maximum water interception capacity
    - 20 times more than default
    - 100% snow interception for moss

Implementing moss and lichen in CLM-FATES

- **Canopy water interceptation**
  - Increase maximum water interception capacity
    - 20 times more than default
    - 100% snow interception for moss
- **Photosynthesis without stomatal control**
  - New “stomotal model” in FATES
  - No root, no btran
  - ***Vcmax*** limited by relative moisture content
  - **Internal leaf CO2 partial pressure** (*Ci*) is not influenced by stomatal conductance but by relative moisture content

$$c_i = c_a - (1.4r_b + 1.6r_s)\, P_{atm} A_n$$

*Ci = Ca - 1.4rb Patm An / max((1.0-fwet)**12,0.000001))*

*Vcmax = Vcmax * min(1.0, fwet/0.6)*

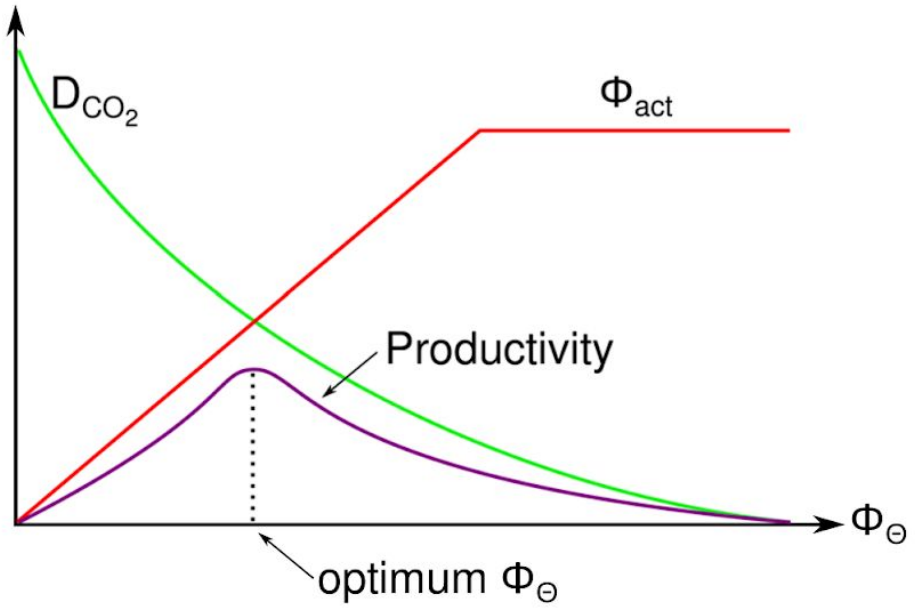


Fig. B12. Effect of water saturation Φ_Θ on CO_2 diffusivity D_{CO_2}, metabolic activity Φ_{act} and on the associated productivity. The productivity has a maximum at an optimum Φ_Θ.

Porada et. al. 2013

Implementing moss and lichen in CLM-FATES

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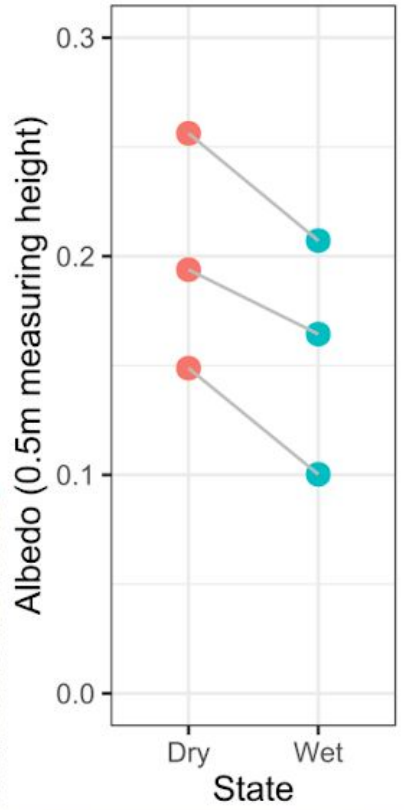
  - V_{cmax} limited by relative moisture content
  - **Internal leaf CO2 partial pressure** (C_i) is not influenced by stomatal conductance but by relative moisture content
- **Optical parameters influenced by water content on albedo**



Preliminary results from Eirik Aasmmo

Implementing moss and lichen in CLM-FATES

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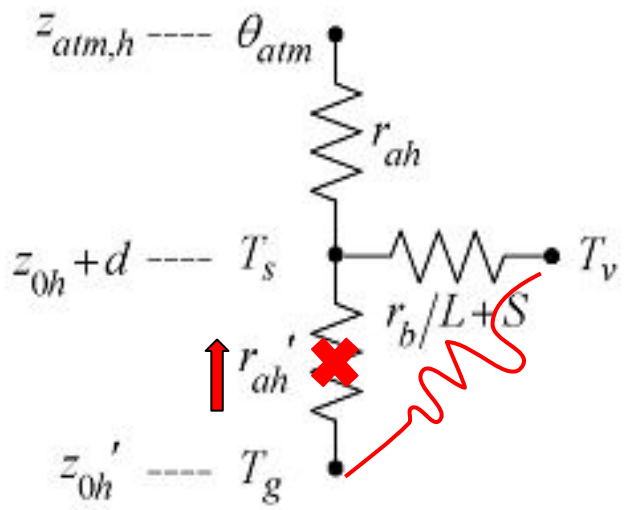
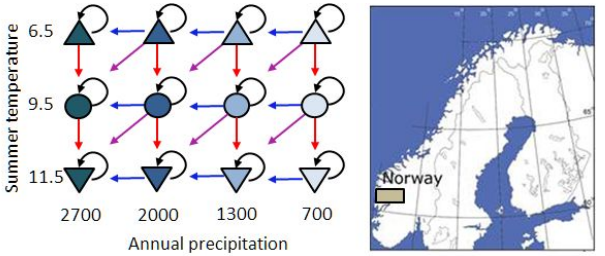
  - ***Vcmax*** limited by relative moisture content
  - **Internal leaf CO2 partial pressure** (*Ci*) is not influenced by stomatal conductance but by relative moisture content
- **Optical parameters influenced by water content on albedo**
- **Thermal and water conductance**
  - No transpiration
  - Reduce ground conductance and leaf boundary conductance
  - Link ground conductance to vegetation temperature?
  - Positive influence by relative water content

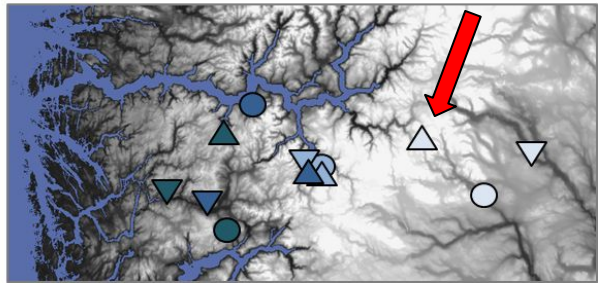


CTSM Tech Documentation

Model experiments using CLM-FATES(SP)

- CLM-FATES(SP):
  - CTSM: fates_main_api (12.01.2021) merged with SP branch from Rosie Fisher
  - FATES: release tag (sci.1.43.2_api.14.2.0) merged with SP branch from Rosie Fisher
  - Some bug fixes related to running CLM-FATES(SP) with single PFT (commented on the SP pull requests)
  - Currently available on local forked CTSM and FATES repositories
- Single site, Single PFT (Grass, Moss, Lichen), 1 year test simulation



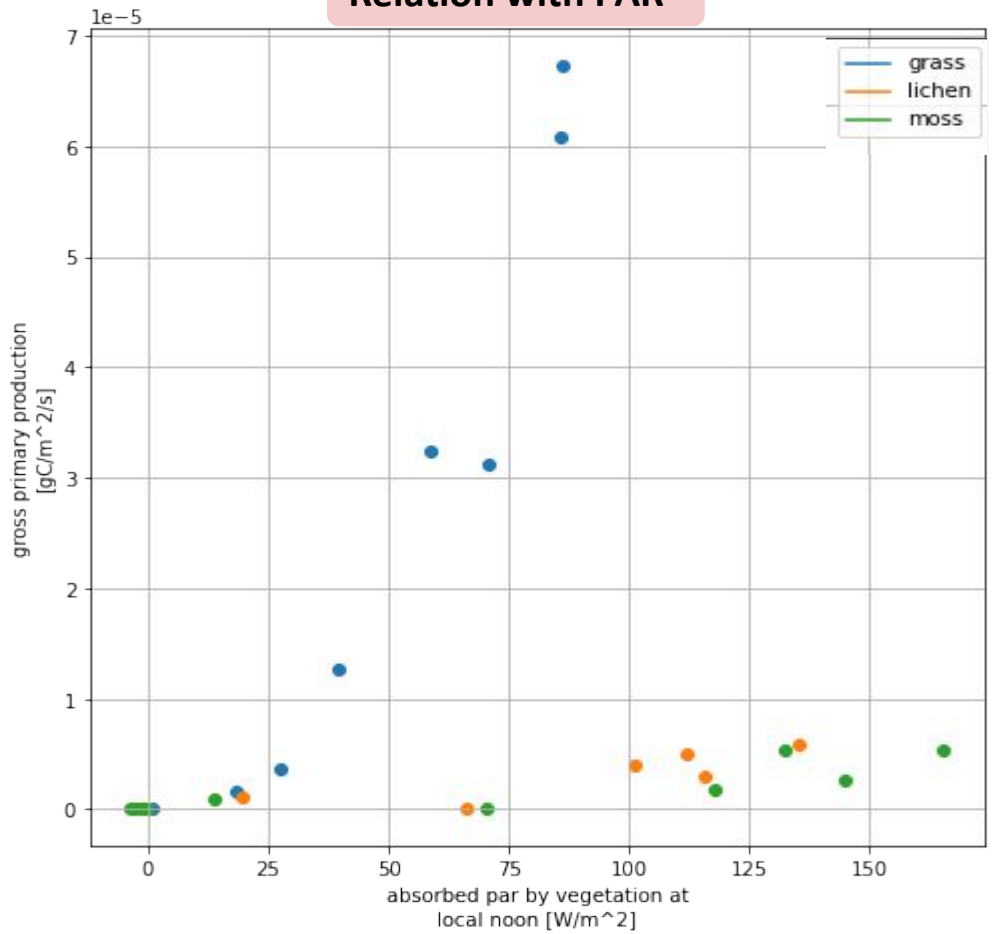


Töpper et al. 2018

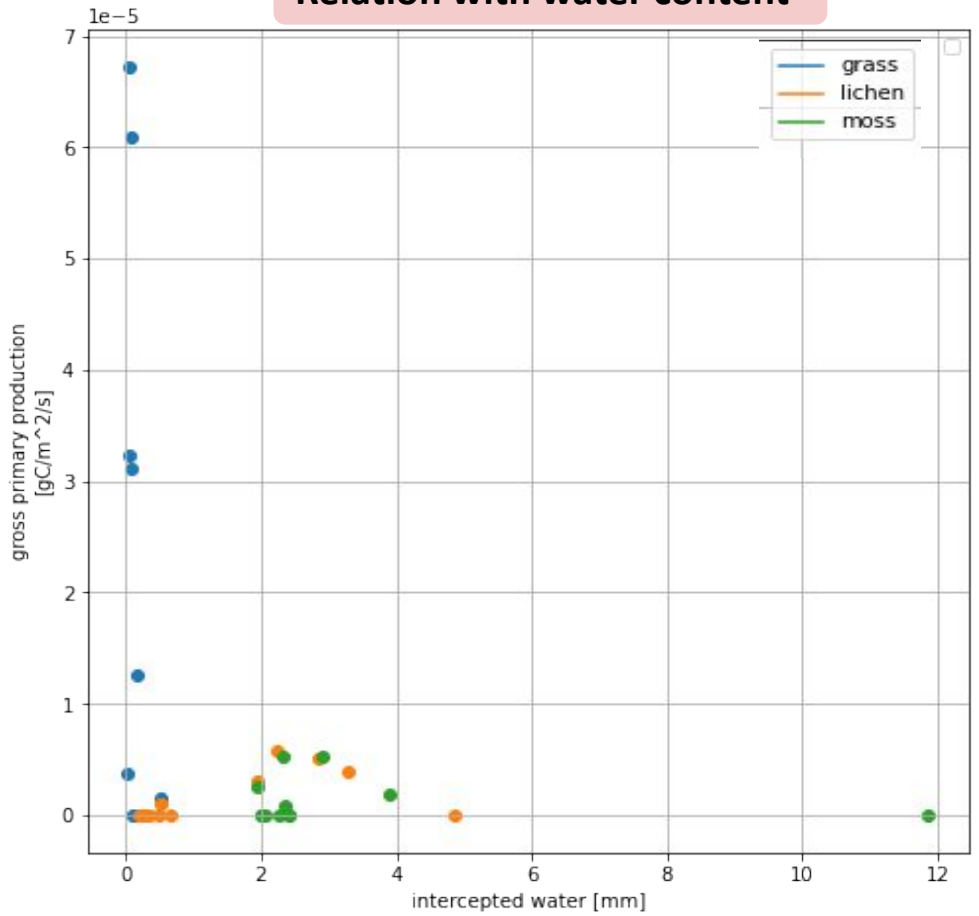
From: Inge Althuizen

Preliminary results - Photosynthetic activity as expected

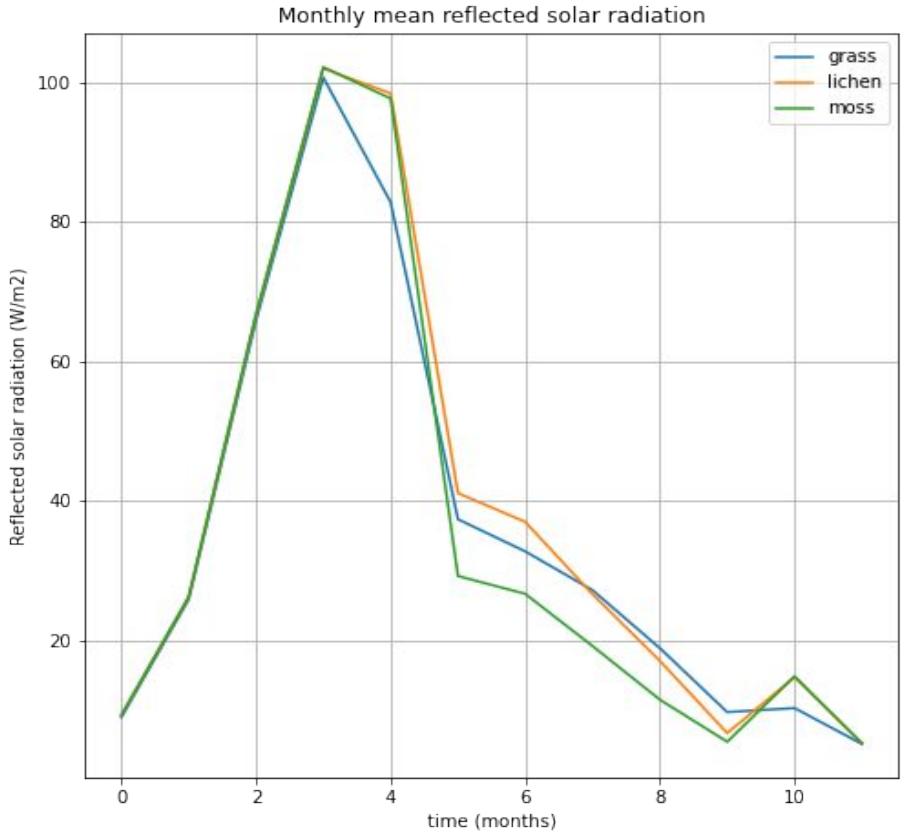
Relation with PAR

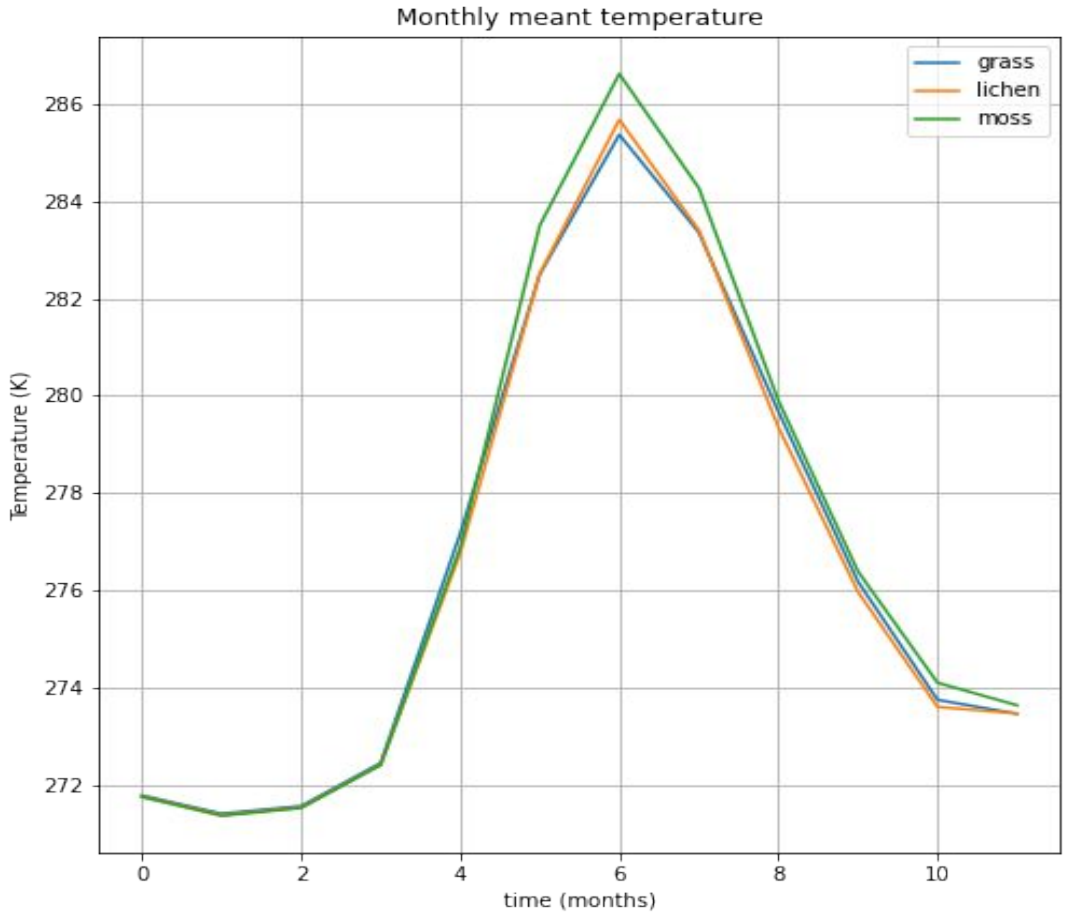


Relation with water content



Preliminary results - Albedo and thermal insulation not as expected yet





Summary

- Potosynthesis work as expected: Lower GPP and reasonable response to water content.
- Albedo and thermal insulation require further work
- CLM-FATES(SP) is an efficient tool for model testing (super fast with one PFT).

Future work

- **Large ensemble site simulations:** futher improve parameterization and benmark the model with observation.
- **Add biogeochemical and demographic processes:** carbon allocation, nutrient cycle, reproduction etc
- **Add moss and lichen as a understorey layer** or grow on other plants
- **Global simulation using CLM-FATES(SP)** with prescribed global distribution of moss and lichen