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EXPLORING THE BIOGEOPHYSICAL AND BIOGEOCHEMICAL IMPACTS OF AN ARCTIC POLEWARD EXPANSION OF THE BOREAL FOREST

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I - INTRODUCTION & OBJECTIVES

WHY?

A poleward migration of vegetation is expected in response to rising surface temperatures, with important implications for the boreal zone and the Arctic. This shift is proposed to have significant impacts on the climate, initiating **biogeophysical and biogeochemical feedback** mechanisms that could either warm or cool the climate (Fig. 1).
Acknowledging the widely recognized impact of albedo change at these high latitudes, some studies argue that the effects associated with biogenic volatile organic compound **(BVOC) emission changes**, which have not received as much attention, **may have a substantial impact** on these pristine regions.

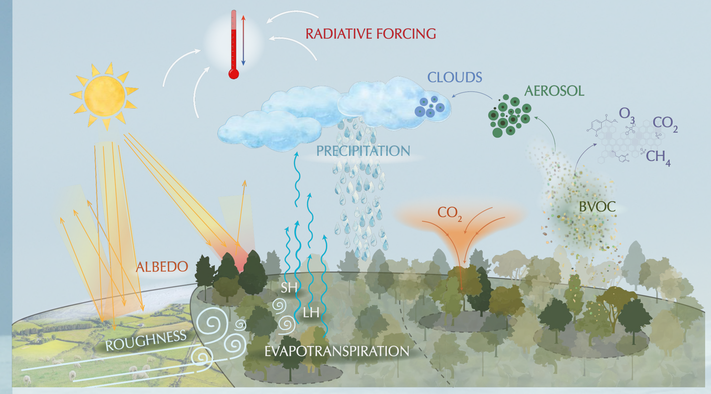


Fig. 1: Illustration of the main biogeophysical and biogeochemical effects related to land use and land cover change. BVOC: biogenic volatile organic compounds, SH: sensible heat flux, LH: latent heat flux

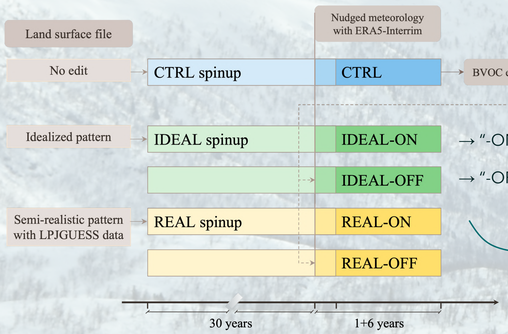
WHAT?

In this study, we focus on investigating the **vegetation-BVOC-SOA-cloud feedback** by using the Norwegian Earth System Model v2, while comparing the relative radiative forcing to the effect of albedo change.

1. Evaluate the total **effective radiative forcing** on climate of the poleward vegetation migration
2. Evaluate the **relative contributions** to the total forcing of the feedbacks related to the **albedo** and **BVOC emission change**
3. Exploring the **vegetation-BVOC-SOA-cloud feedback** by tracing the signal throughout the loop

II - METHODS

SIMULATION SETUP

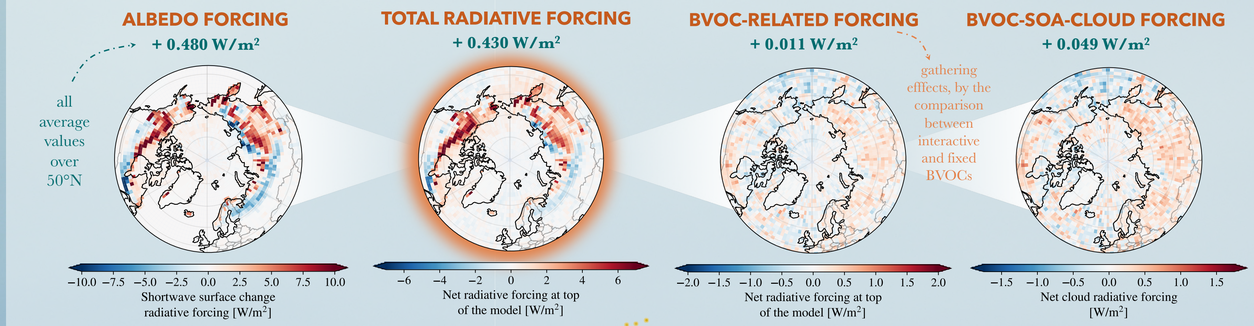


The albedo and BVOC-SOA-cloud feedbacks are explored through a **modelling approach by running NorESM2**

- coupled atmosphere CAM6-Nor and land CLM5 components, fixed sea-surface temperature
- PD (present day) climate

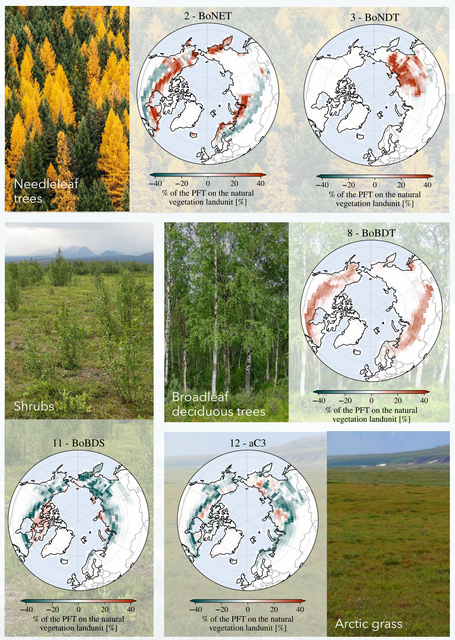
-ON	CTRL	→ ALL EFFECTS COMBINED
-ON	-OFF	→ BVOC-RELATED EFFECTS

III - RESULTS



BOREAL PFT CONFIGURATION CHANGE

The semi-realistic change is performed by processed data from the dynamic vegetation model LPJ-GUESS forced with GFDL-ESM4 atmospheric forcing in the SSP58.5 scenario (*Tang at al., 2021*).



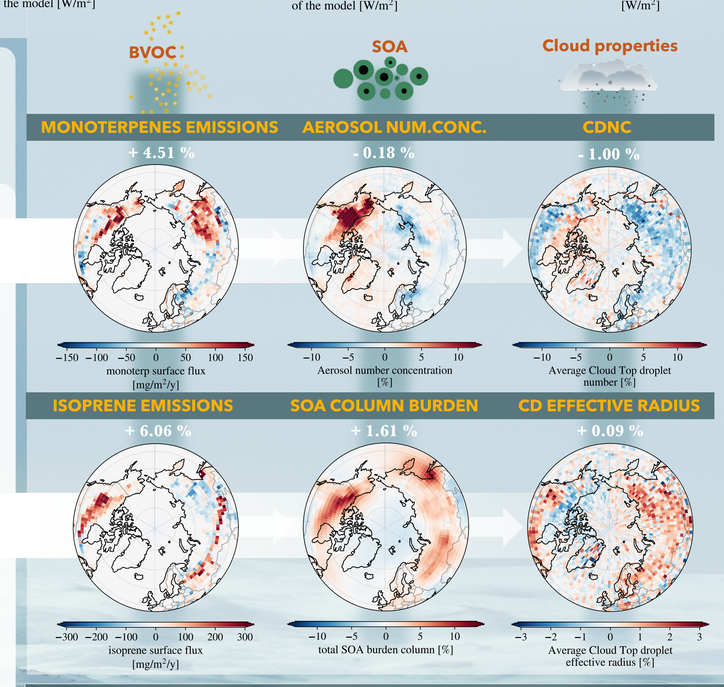
The idealized perturbation is given by a replacement scheme (trees over shrubs, shrubs over grass).

Note: only the configuration changes and outputs related to the semi-realistic perturbation are illustrated here.

DECOMPOSITION OF THE TOTAL RADIATIVE FLUX [2]:

$$F_{tot} = F_{dir} + F_{cloud} + F_{rest}$$

F_{dir}: direct effect from light scattering and absorption by aerosols
F_{cloud}: scattering and absorption by **clouds**
F_{rest}: other possible contributions to the forcing, mainly referring to land surface changes (i.e. **albedo**)

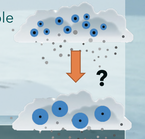


BVOC: biogenic organic compounds
SOA: secondary organic aerosol
PFT: plant functional type
CDNC: cloud droplet number concentration

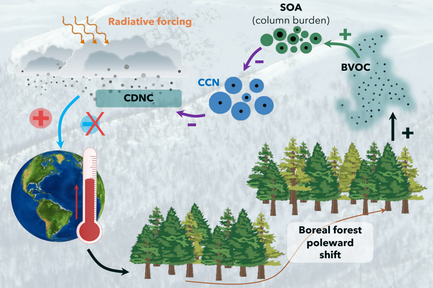
- Spatial patterns of **isoprene and monoterpenes emissions** follow the vegetation change – i.e. replacement of broadleaf deciduous trees over the conifers, expansion of conifers over the Arctic

- A spatial relationship between BVOC emissions and their effect on **aerosol properties** seems to be present, but the overall contribution over the region appears to weaken.

- **Cloud properties exhibit a weak and noisy signal**, and the spatial relationship is barely recognizable



IV - CONCLUSIONS & OUTLOOK



- Overall **warming effect**
- **Albedo change dominates** the total forcing
- **BVOC-related** contribution is much **weaker** and – surprisingly- **positive**
- Overall, the BVOC change appears to cause a decrease in the number of aerosol and cloud droplets, while increasing their size
- Further investigation and analysis is needed to have a better understanding of these processes
- Other simulations are planned to integrate the active atmospheric chemistry (MOSART model [3])

References:
[1] Tang et al. (2023) https://doi.org/10.1038/s41612-023-00463-7
[2] Ghan, S. J. (2013) https://doi.org/10.5194/acp-13-9971-2013, 2013.
[3] Oliviè et al., in prep

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ABSTRACT
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