Snow dynamics impacts on temperate / high latitude climate

Proposed by IPSL (LSCE and LMD teams)

Ph. Peylin, C. Ottlé, F. Chéruy

Main project objective

⇒ Improve our understanding of snow-vegetation-atmosphere feedbacks, with the IPSL climate model (LMDZ-ORCHIDEE) and various CCI products (especially snow products)

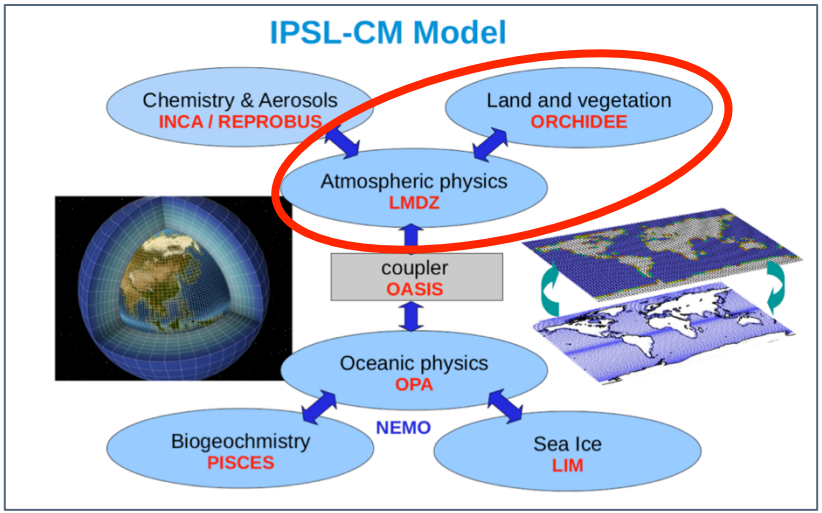
Rationale

⇒ Climate predictions are highly sensitive to surface albedo/temperature in cold regions impacted by snow

⇒ Recent work performed in CCI-HRLC project show that a change in land cover can impact snow cover & albedo and surface temperature, inducing modifications in the air temperature, rainfall/snowfall partition leading to a positive feedback loop in the IPSL model !

Models / Tools

- Use of LMDZ-ORCHIDEE models(including multi-layer snow scheme)

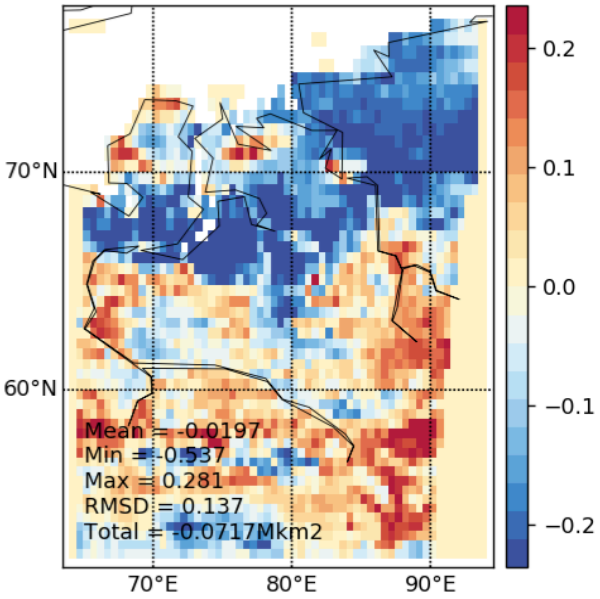


Example over Siberia (coupled land-atmosphere model study):

⇒ New HRLC ⇒ reduction of tree cover up to 20% in the northern part of the domain,
+ revision of albedo scheme (snow and veg)

New HRLandCover minus old MRLandCover (mean over 2005-2014)

Diff. in Tree Cover



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⇒ New HRLC ⇒ reduction of tree cover up to 20% in the northern part of the domain,
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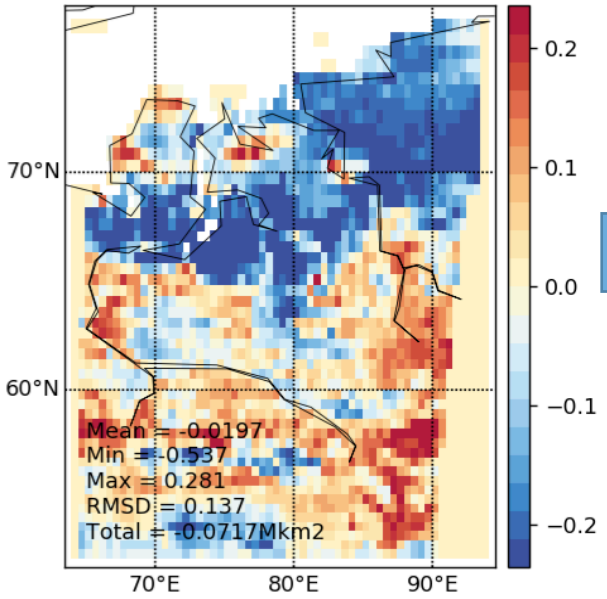
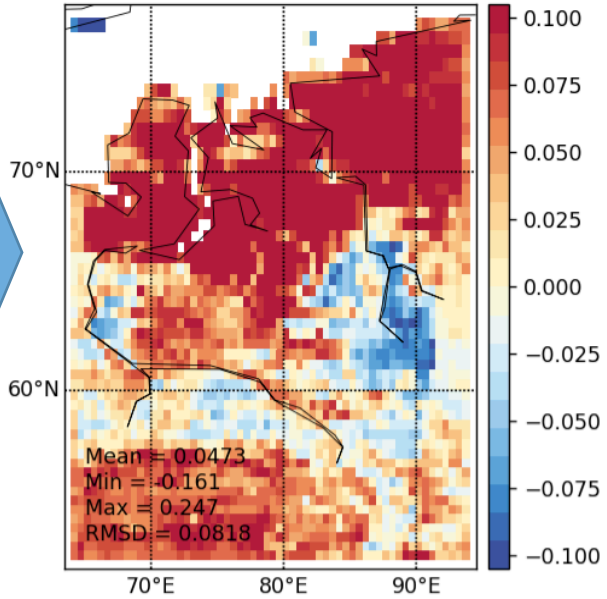
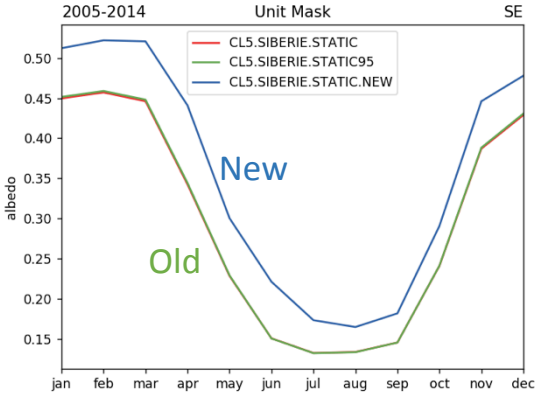


Diff. in Albedo



Seas. Cycle Albedo



Example over Siberia (coupled land-atmosphere model study):

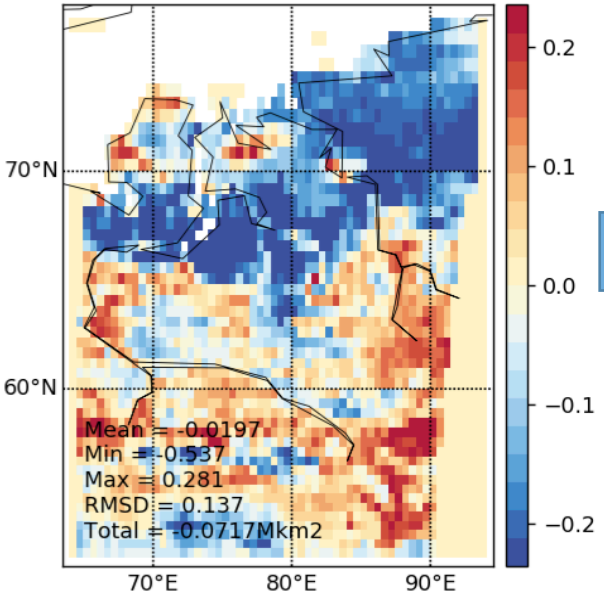
⇒ New HRLC ⇒ reduction of tree cover up to 20% in the northern part of the domain,

⇒ Increased the surface albedo up to 10% in annual mean (3% in summer),

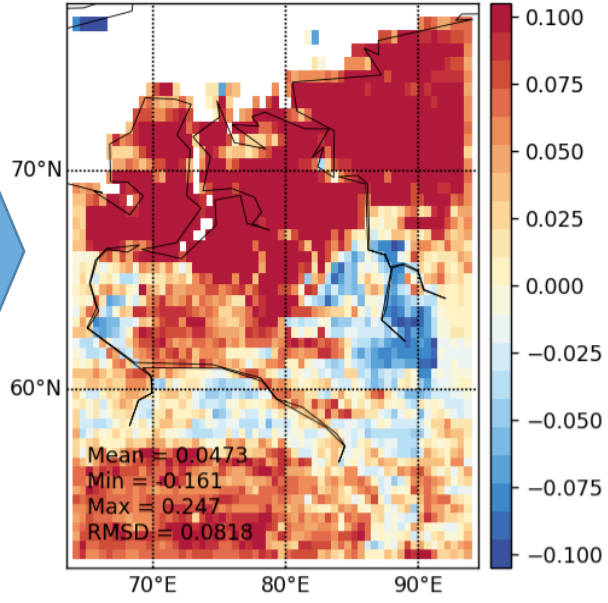
⇒ Decreased the air temperature up to 3 K (mainly in spring - summer)

New HRLandCover minus old MRLandCover (mean over 2005-2014)

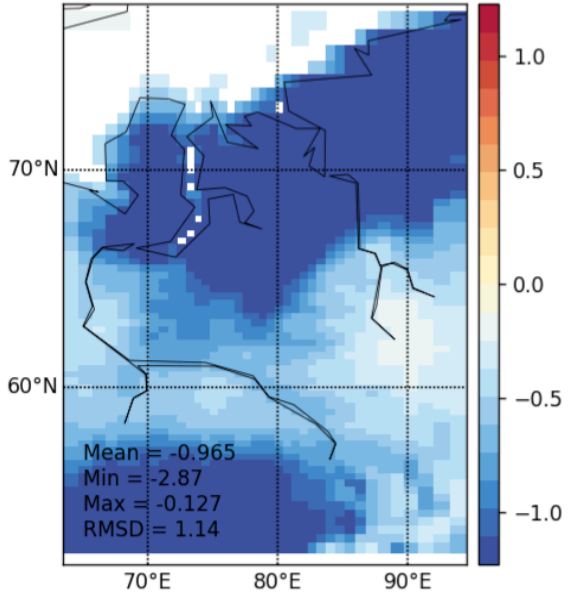
Diff. in Tree Cover



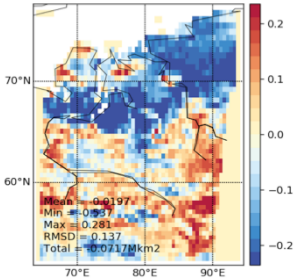
Diff. in Albedo



Diff. in Air temperature

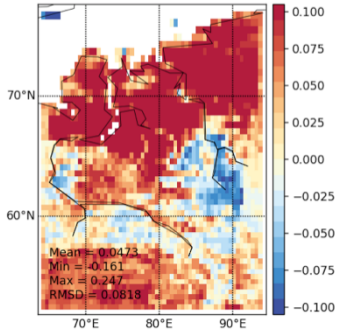


Potential feedback loop induced by land cover /albedo changes (in the model)

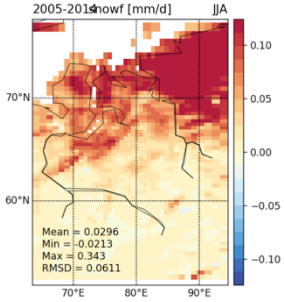


Decrease of tree cover

Longer & larger snow cover fraction

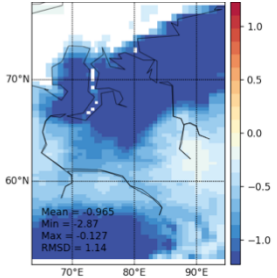


Higher albedo



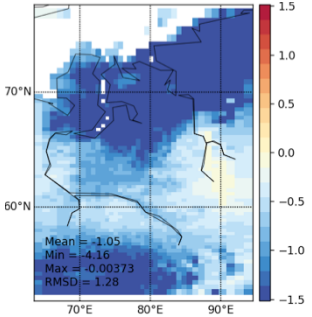
More snow fall in JJA

feedback



Cooler air temperature

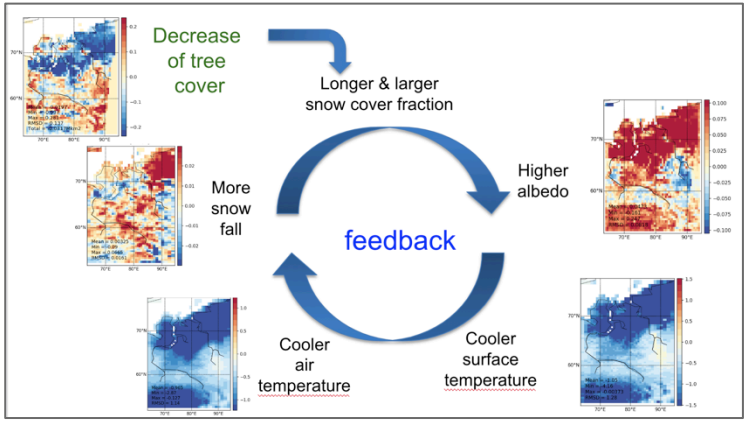
Cooler surface temperature



Specific Objectives - Approach

⇒ What does the CCI-data can tell us about the potential “LC - Snow - Climate” feedbacks over the last decades ?

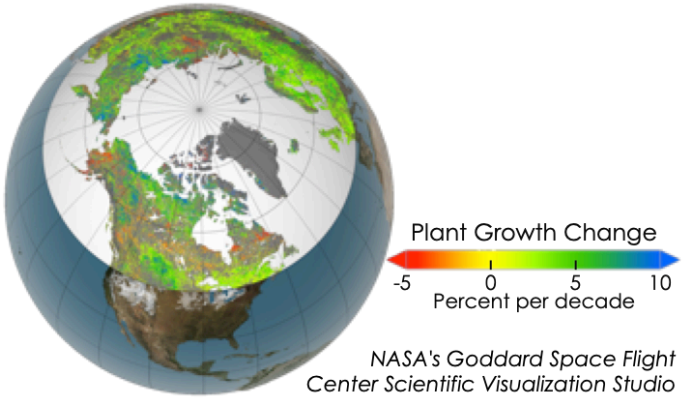
⇒ Can we improve such representation in the ORCHIDEE-LMDZ model ?



Shrub expansion in the Arctic

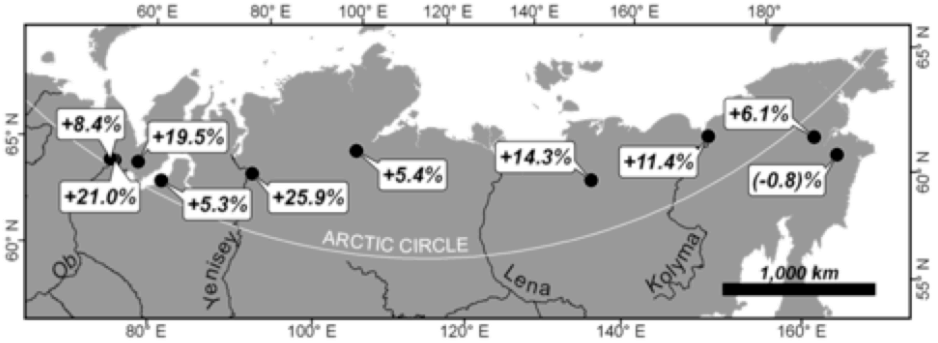
Today and tomorrow:

➔Arctic greening



NASA's Goddard Space Flight Center Scientific Visualization Studio

➔Shrubification (= shrub cover increase)



Frost and Epstein, 2014

Planned work

- **Data Analysis (WP1)**
  - Consistency check/analysis between Snow Cover (mass & extent) and Land Cover dynamics and other CCI products (LST; Fire; Biomass)
    - CCI-SNOW (SCF and SWE): MODIS (1km, 2000 - 2020) and AVHRR (5 km, 1982 - 2018)
      Making use of SCFV (top of forest) versus SCFG (ground cover)
    - MR-HR Land Cover : 300 / 30 m data mapped onto PFT at 1km
    - LST (0.05°, 1995-2020); Fire (MODIS; 2001 - 2020); BIOMASS (3 epoch data 1990, 2010, 2018)
  - => Analysis of the differences btw short & tall vegetation and Deciduous & Evergreen

- **ORCHIDEE model evaluation (WP1)**
  - Evaluate the simulated snow cover dynamics (mass and extent) in ORCHIDEE using prescribed climate forcing ERA5
  - Define a set of key “homogeneous points” for the optimisation step

Planned work

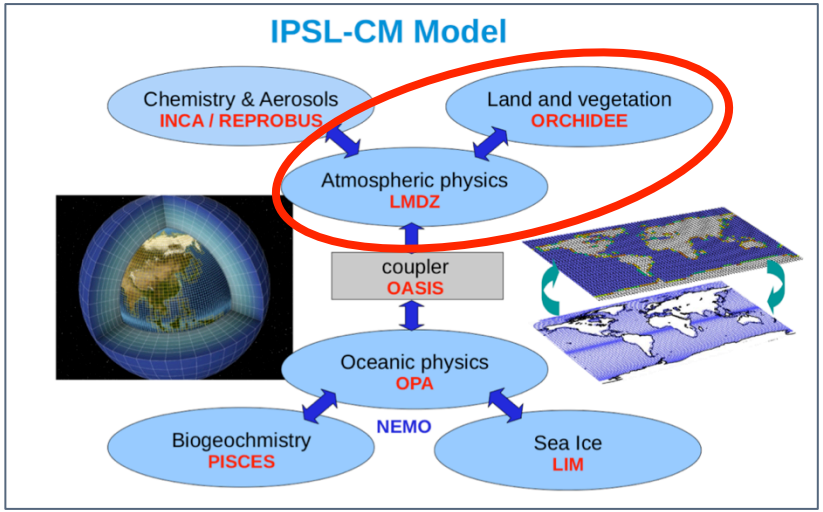
- **Model improvement (WP1 & Synergies with others projects)**
  - Account for Shrubs & the representation of Snow - Veg dynamics in ORC (Druel et al. 2019): Work in collaboration with ongoing H2020 GreenFeedback project)
  - Improving soil thermics (carbon impact on soil thermal properties; ongoing work)

- **Model optimisation (WP2)**
  - Model sensitivity experiments to identify key parameters (Moris / Sobol approaches)
  - Multi-site optimisation (local/global approaches, History Matching…) using SCF and SWE data

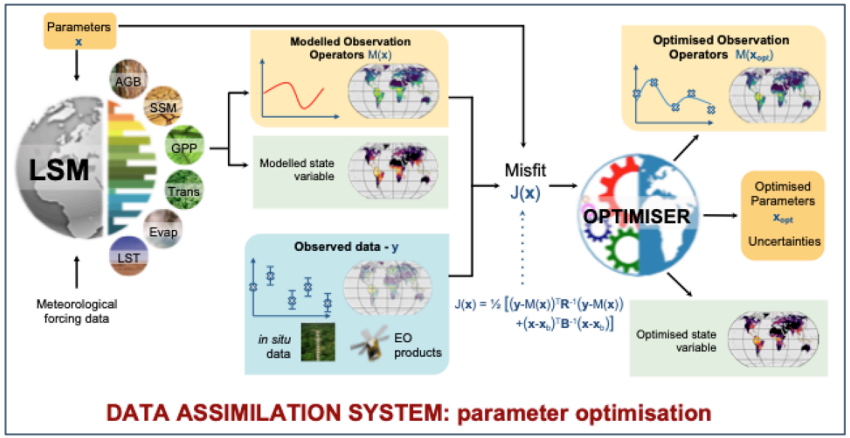
- **Coupled Model simulations (WP3 - not funded yet !)**
  - Use the Coupled LMDZ - ORCHIDEE model (AMIP type simulation (fixed SST, SIC)
  - Historical simulations to analyse the impact of “improved snow model” on the feedbacks

Models / Tools

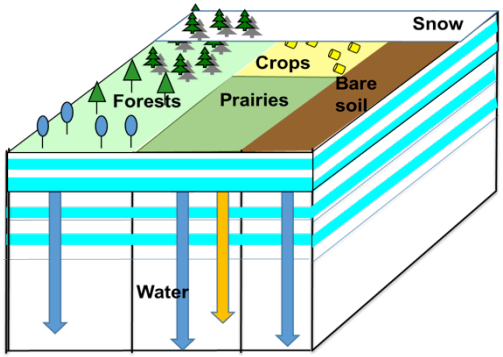
- Use of LMDZ-ORCHIDEE models (including multi-layer snow scheme)



- Use of parameter optimization / calibration tools (ORCHIDAS system)



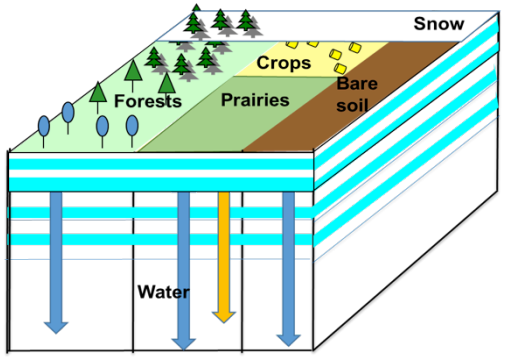
Snow Energy budget & Snow model



In presence of snow:

- Partial snow cover
- Specific Energy budget for snow to model snowpack evolution
- Grid energy budget modified to account for snow impacts on albedo, surface roughness, sublimation, soil temperature, …

Snow Energy budget & Snow model



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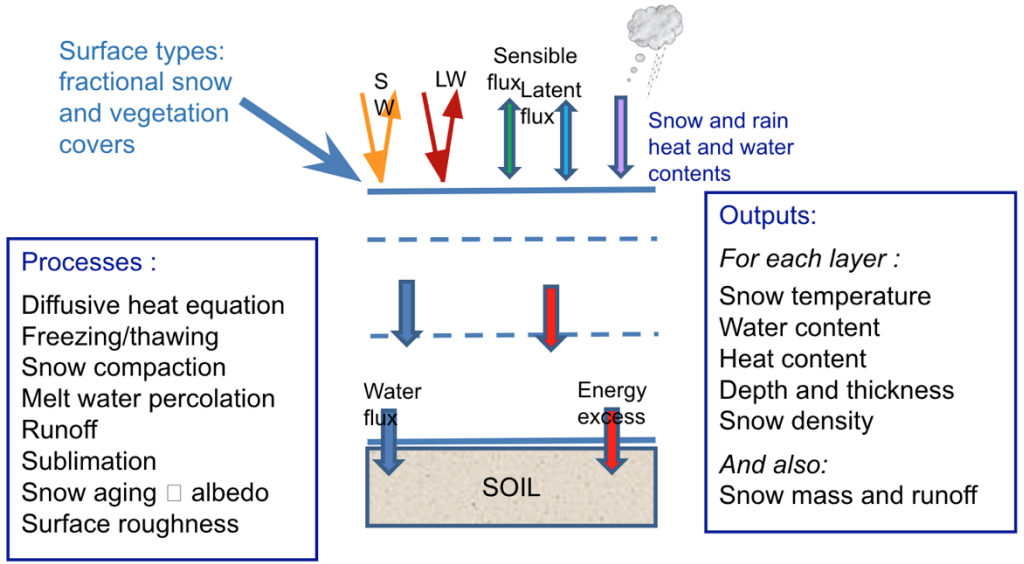
Snow model:

- 3 layers snow model for vegetated and bare soil surfaces
- Same model for ice sheets and glaciers

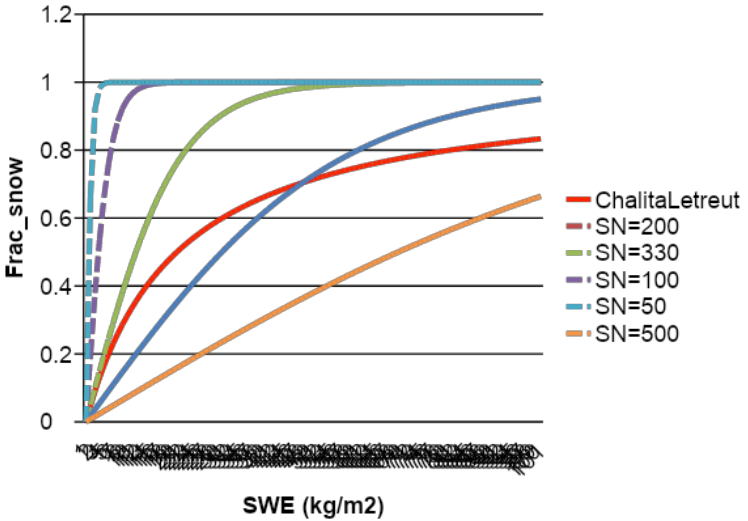


Snow cover fraction & snow albedo in ORCHIDEE

- Snow cover fraction depend on snow mass and density (Swenson & Lawrence, 2012)

$$frac_{snow} = tanh\left(\frac{snowdepth}{0{,}025 * snowrho * 50.}\right)$$

SN



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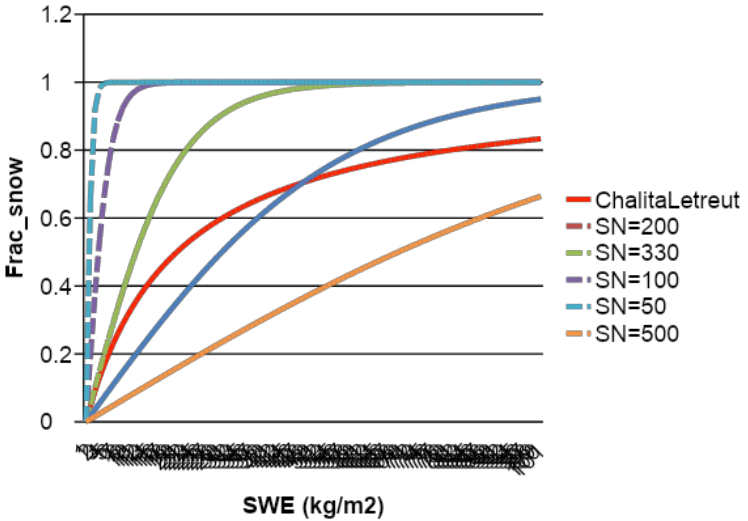

- Albedo depends on snow age (Chalita and LeTreut 1994)

Age = f (PFT)

$$age(t+\delta t) = \left(age(t) + \left(1 - \frac{age(t)}{maxsnowage}\right) * dt\right) * exp\left(-\frac{\delta_{snow}}{snowtrans}\right)$$

$$Albedo = alb_{aged} + alb_{dec} * exp\left(\frac{-age}{tcstsnowa}\right)$$

Time constants

Thank you…

Shrub expansion in the Arctic

Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities

Isla H Myers-Smith[1,2], Bruce C Forbes[3], Martin Wilmking[4], Martin Hallinger[4], Trevor Lantz[5], Daan Blok[6], Ken D Tape[7], Marc Macias-Fauria[8], Ute Sass-Klaassen[6], Esther Lévesque[9] + Show full author list

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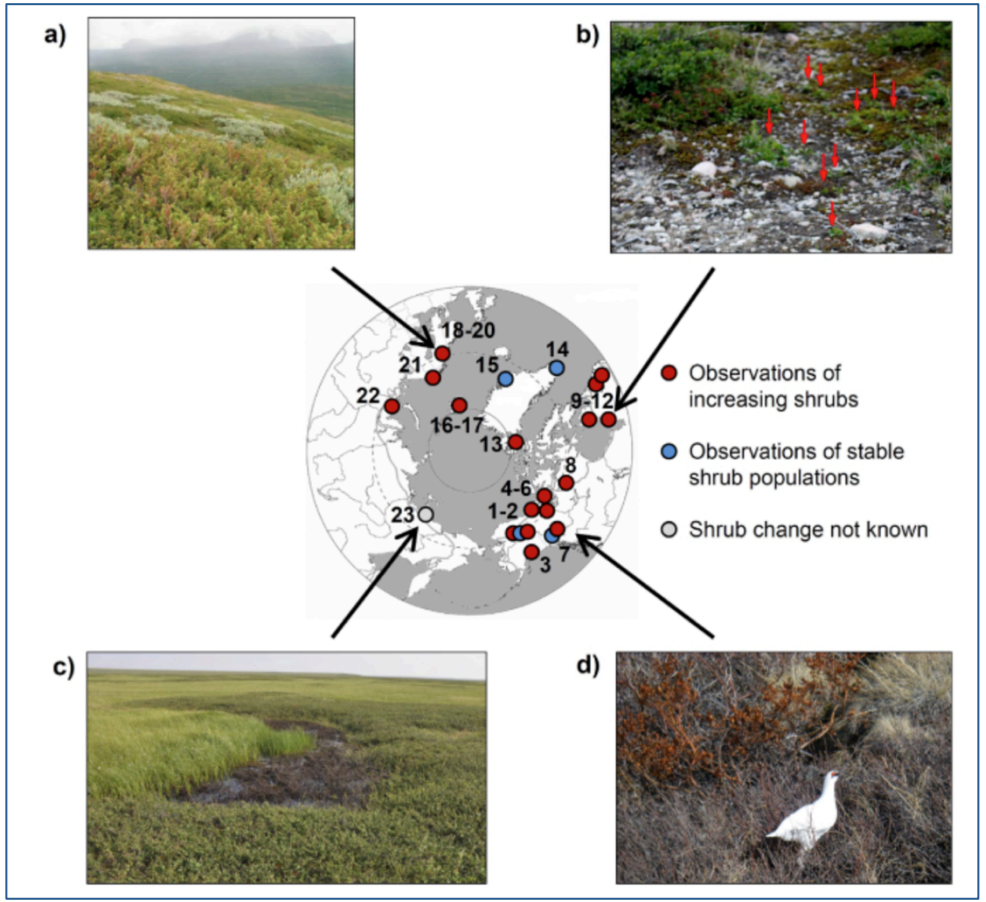

Figure 2. Map of sites at high latitudes where shrub change has been observed and some examples of shrub change.