

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)

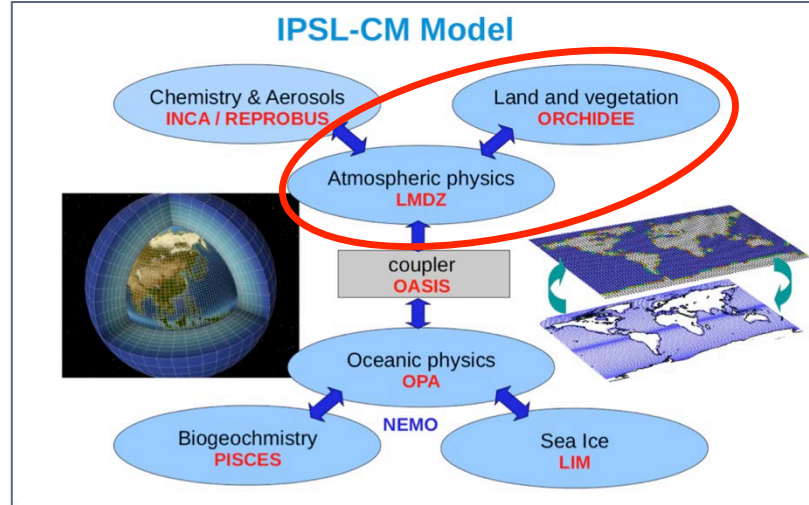
Rationale

⇒ 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)

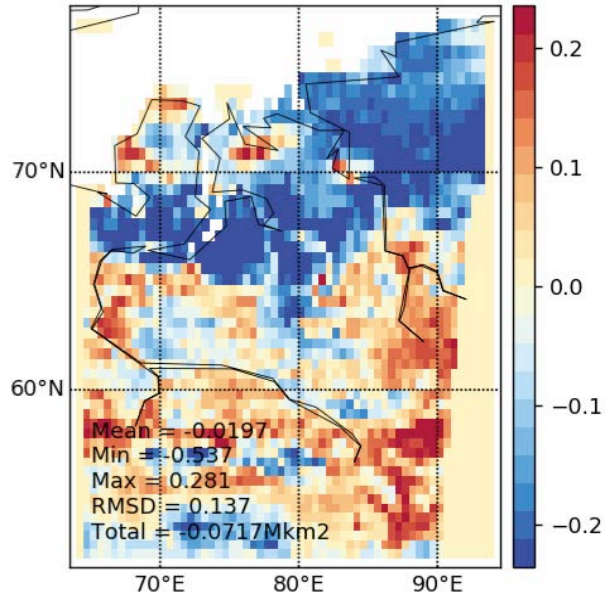


Example over Siberia (coupled land-atmosphere model study):

⇒ 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

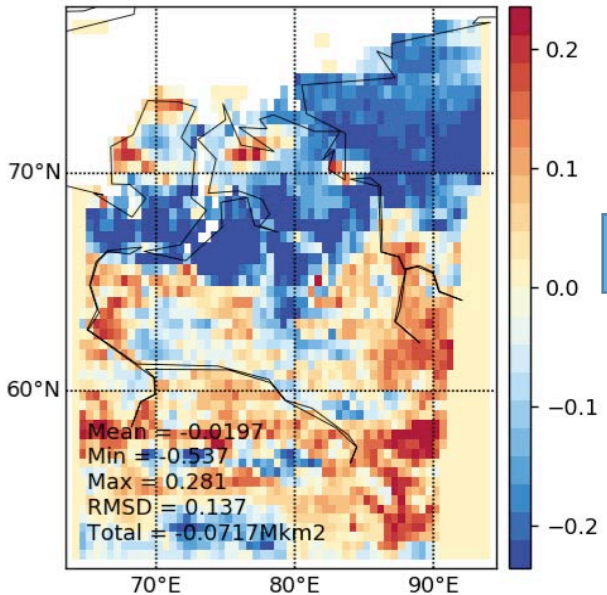


Example over Siberia (coupled land-atmosphere model study):

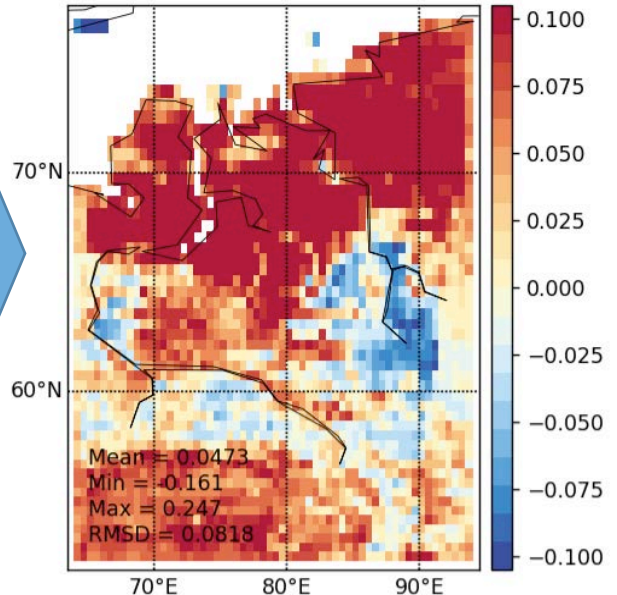
- ⇒ New HRLC ⇒ reduction of tree cover up to 20% in the northern part of the domain, + revision of albedo scheme (snow and veg)
- ⇒ Increased the surface albedo up to 10% in annual mean (3% in summer)

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

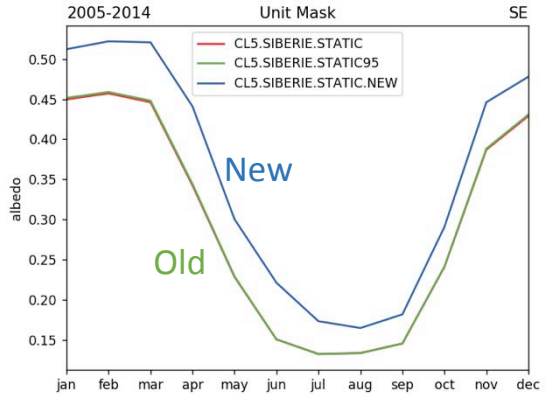
Diff. in Tree Cover



Diff. in Albedo



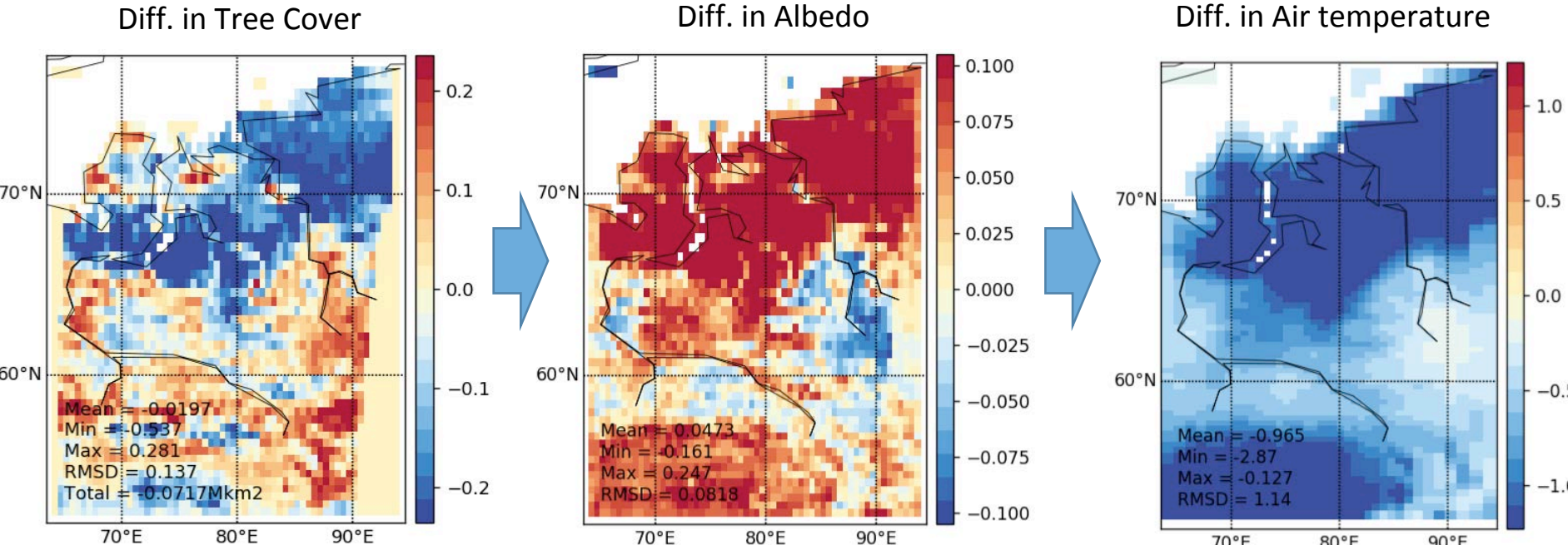
Seas. Cycle Albedo



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)



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

Decrease
of tree
cover



Longer & larger
snow cover fraction

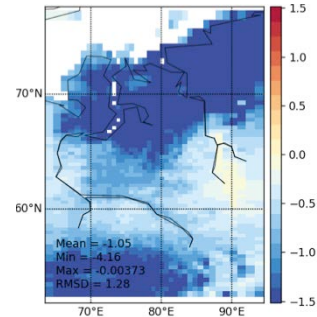
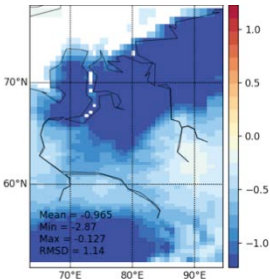
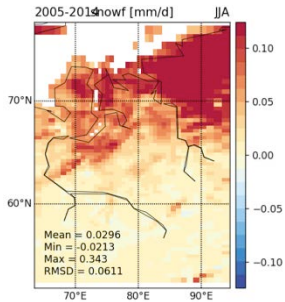
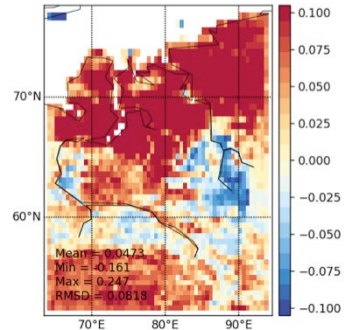
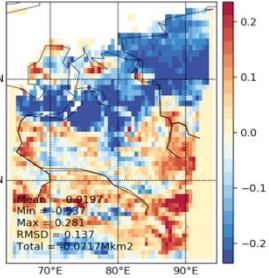
Higher
albedo

feedback

More
snow
fall
in JJA

Cooler
air
temperature

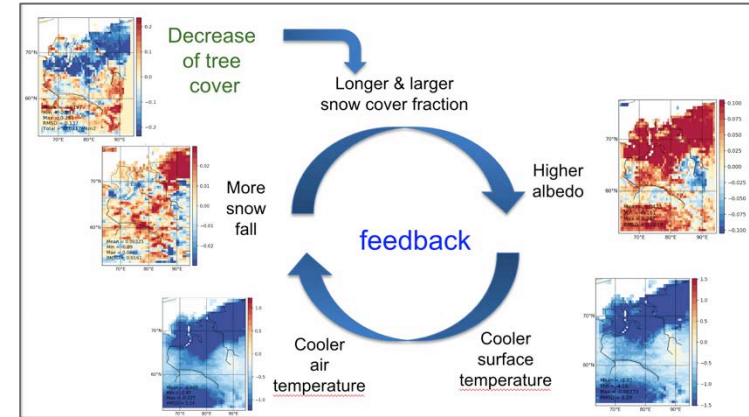
Cooler
surface
temperature



Specific Objectives - Approach

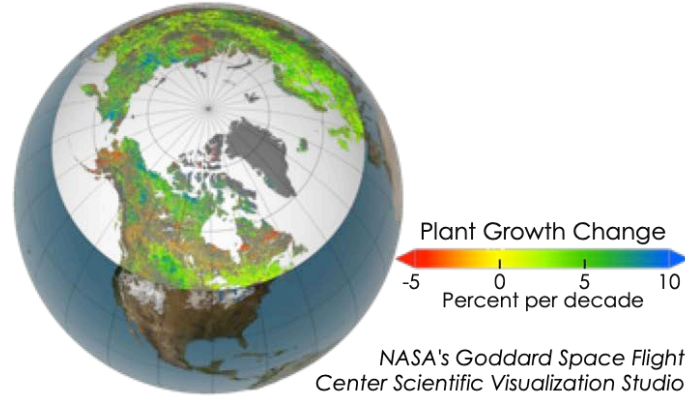
⇒ What does the CCI-data can tell us about the potential “LC - Snow - Climate” feedbacks over the last decades ?

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

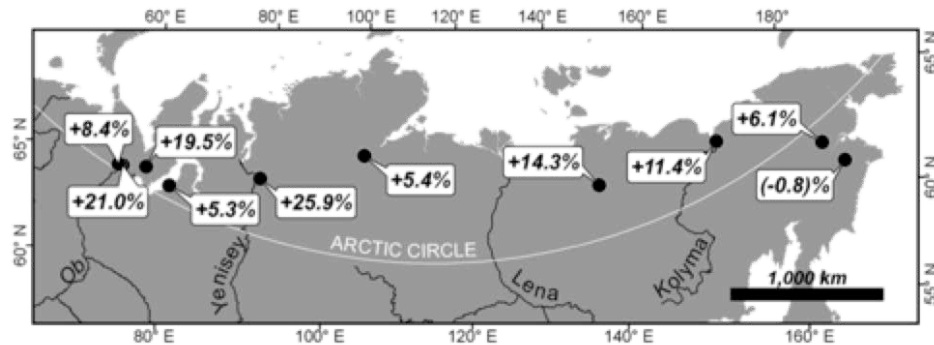


Shrub expansion in the Arctic

Today and tomorrow:
→ Arctic greening



→ 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

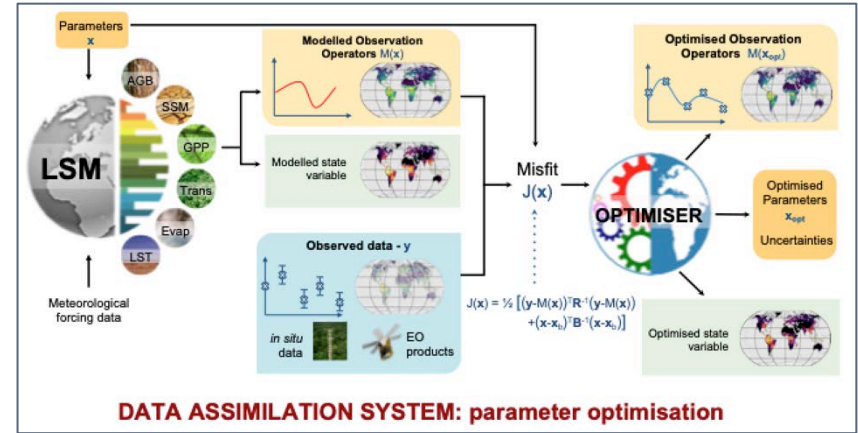
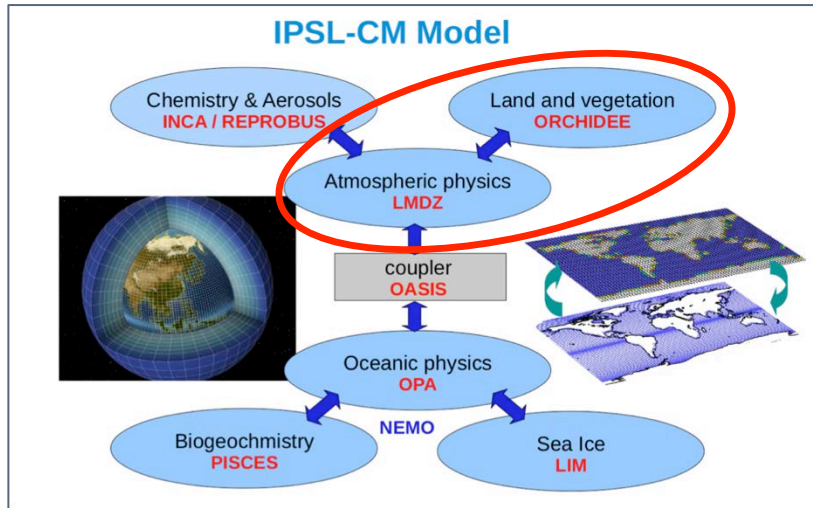
Planned work

- **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

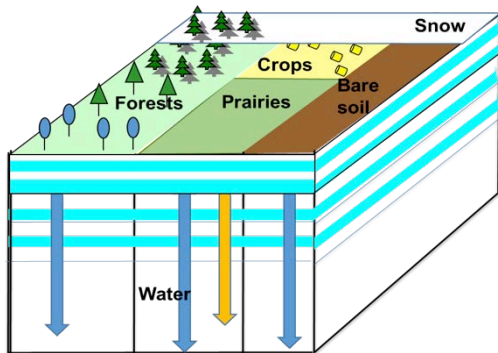
Models / Tools

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

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



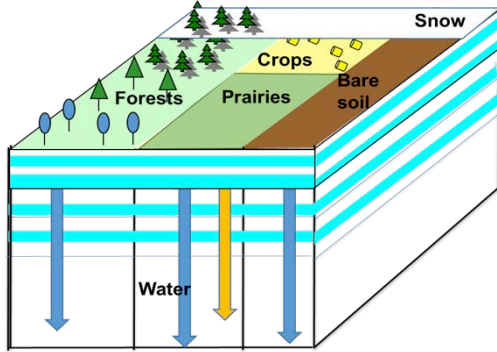
Snow Energy budget & Snow model



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

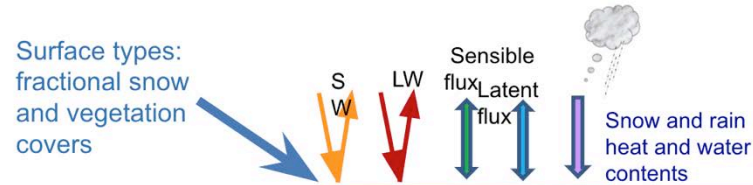


In presence of snow:

- 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, ...

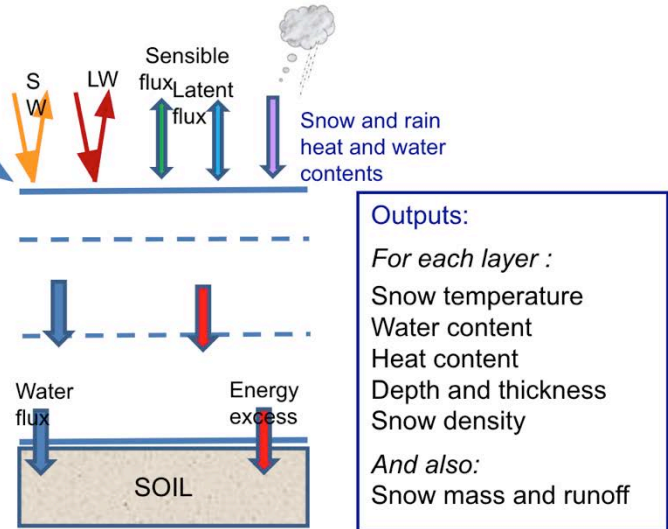
Snow model:

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



Processes :

Diffusive heat equation
Freezing/thawing
Snow compaction
Melt water percolation
Runoff
Sublimation
Snow aging \square albedo
Surface roughness

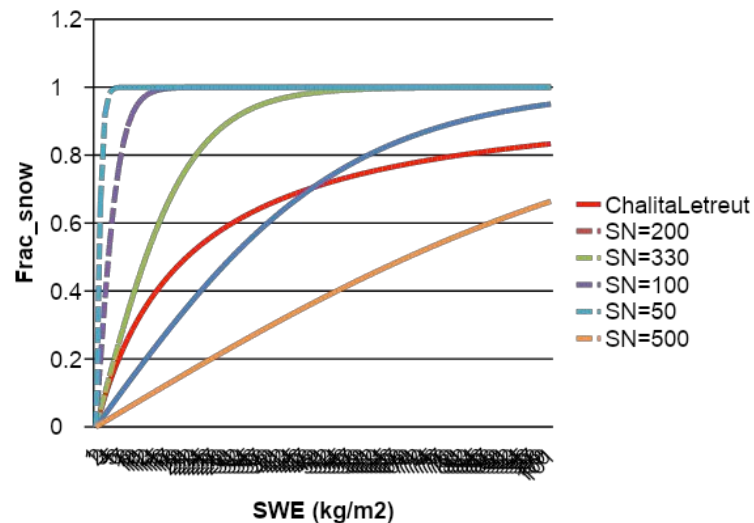


Snow cover fraction & snow albedo in ORCHIDEE

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

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

SN

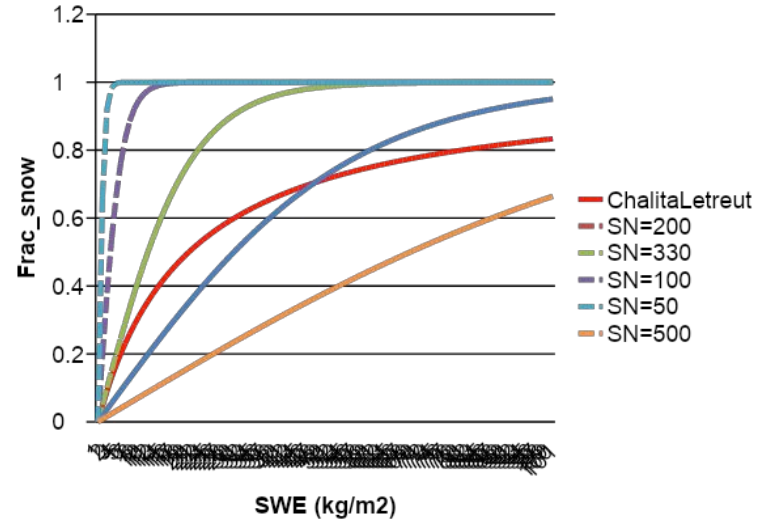


Snow cover fraction & snow albedo in ORCHIDEE

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

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

SN



- Albedo depends on snow age (Chalita and LeTreur 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 Forbes³, Martin Wilkming⁴, Martin Hallinger⁴, Trevor Lantz⁵, Daan Blok⁶, Ken D Tape⁷, Marc Macias-Fauria⁸, Ute Sass-Klaassen⁶, Esther Lévesque⁹ + [Show full author list](#)

Published 20 December 2011 • © 2011 IOP Publishing Ltd

[Environmental Research Letters](#), Volume 6, Number 4

Citation Isla H Myers-Smith *et al* 2011 *Environ. Res. Lett.* 6 045509

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

