On-going calibration of the snow model using ESA-CCI snow MODIS products and ORCHIDAS tools

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LSCE

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1) ESA-CCI Snow Products

- Snow cover fraction
- Snow Water Equivalent

Snow Cover Fraction (SCF)

Percentage of the ground covered by snow

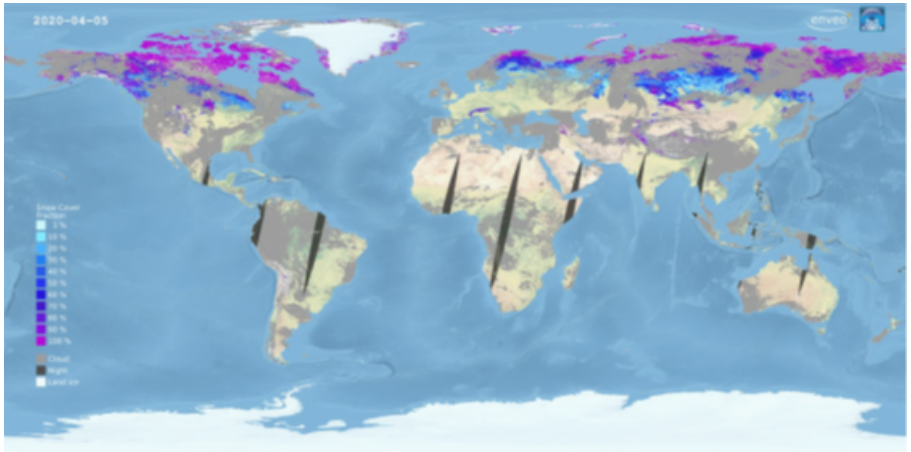
Two types of SCF:

- **Visible** (SCFV): as seen from space
- **Ground** (SCFG): calculated by correcting the masking effect of the canopy layer

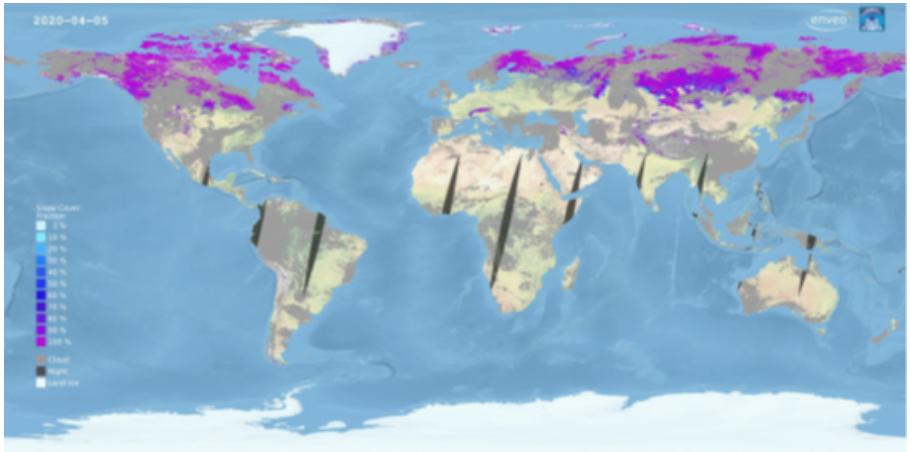
Determined from four optical sensors - almost 40 years of data combined

20 years of data with MODIS (2000-2020) at 0.01° and daily resolution

SCFV and SCFG examples



SCFV (from MODIS on 5 April 2020) [1]



SCFG (from MODIS on 5 April 2020)

- Higher values of SCFG linked to the presence of the canopy
- Available for sun-lit cloud-free areas (except for land ice regions)
- Global coverage

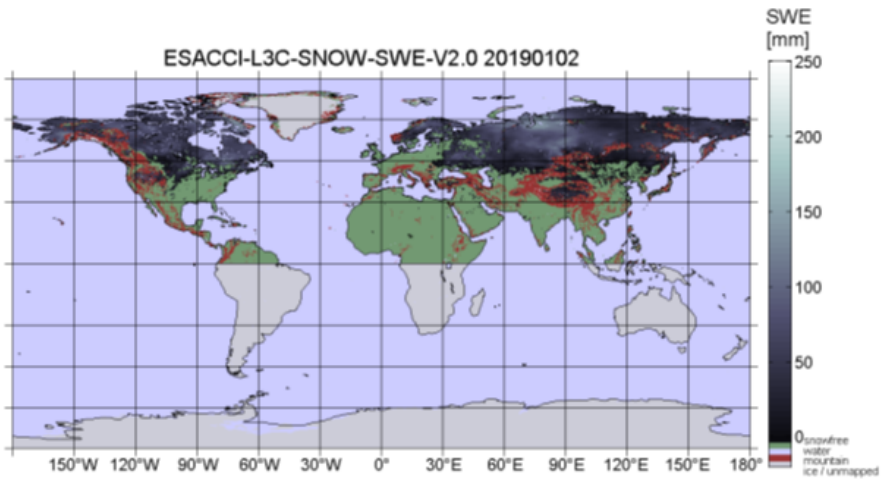
1. (Solberg et al. 2021)

Snow Water Equivalent (SWE)

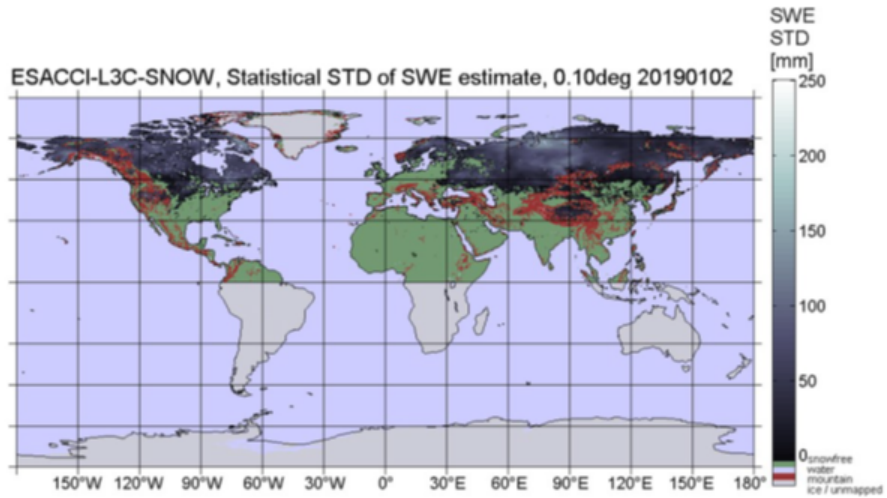
Height of the equivalent column of water

$$SWE = \frac{\rho_{snow}}{\rho_{water}} \times SD \qquad \text{with } \rho_{snow} = 240 \text{ kg} \cdot \text{m}^{-3}$$

Combination of data from four microwave sensors (1979-2020) ➞ Not affected by the clouds



SWE (2 January 2019) [2]



SWE estimate of STD (2 January 2019)

- Spatial resolution: 0.1° / Temporal resolution: daily
- Significant uncertainties
- Only available for the Northern hemisphere and no data for mountaineous areas

2. (Solberg et al. 2021)

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2) Impact of vegetation on SCF via observations and comparison with ORCHIDEE

- Highlighting of the influence of the vegetation on the SCFV and SCFG
- Comparison of the SCF calculated by ORCHIDEE with the ESA-CCI Snow product SCFG

Impact of the vegetation on the snow cover fraction

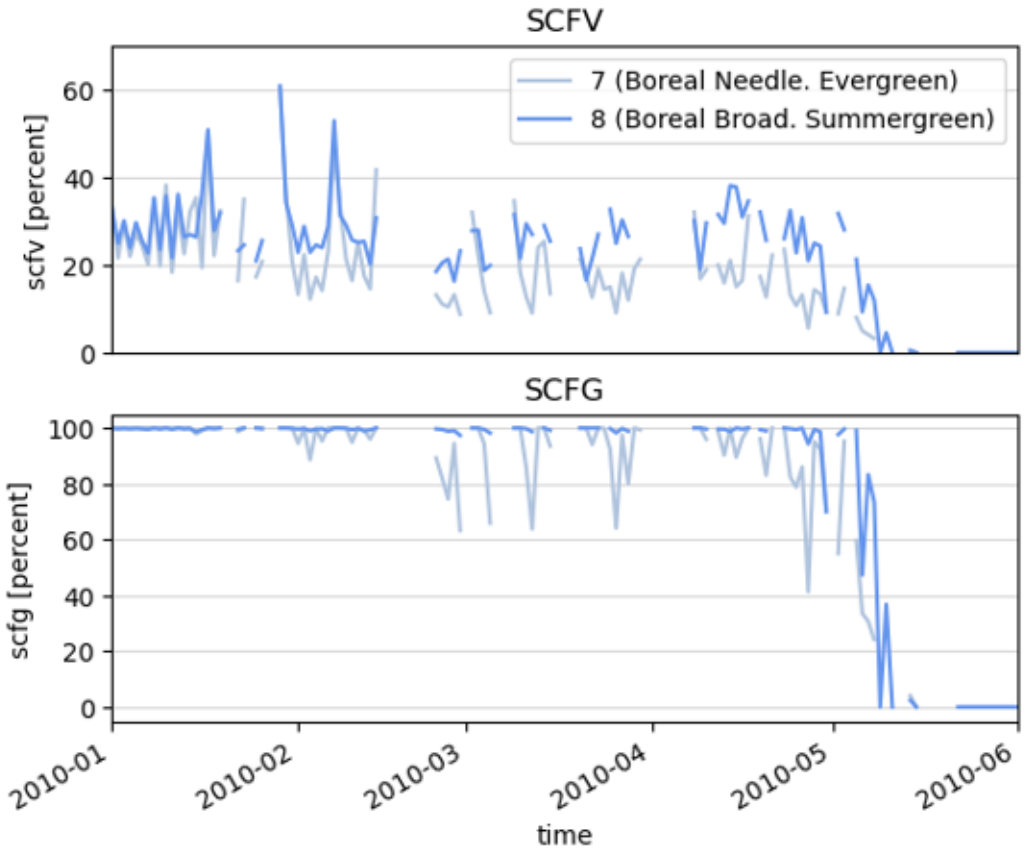
Selection of a small region in Siberia ($1° \times 1°$) with the presence of boreal needleleaf evergreen vegetation (PFT7) and boreal broadleaf summergreen vegetation (PFT8)

Spatial averaging of the SCF for each PFT

➟ Lower SCFV for PFT 7 than PFT 8

➟ Closer values between the two PFTs for the SCFG

Emphasizes the impact of the vegetation on the SCF

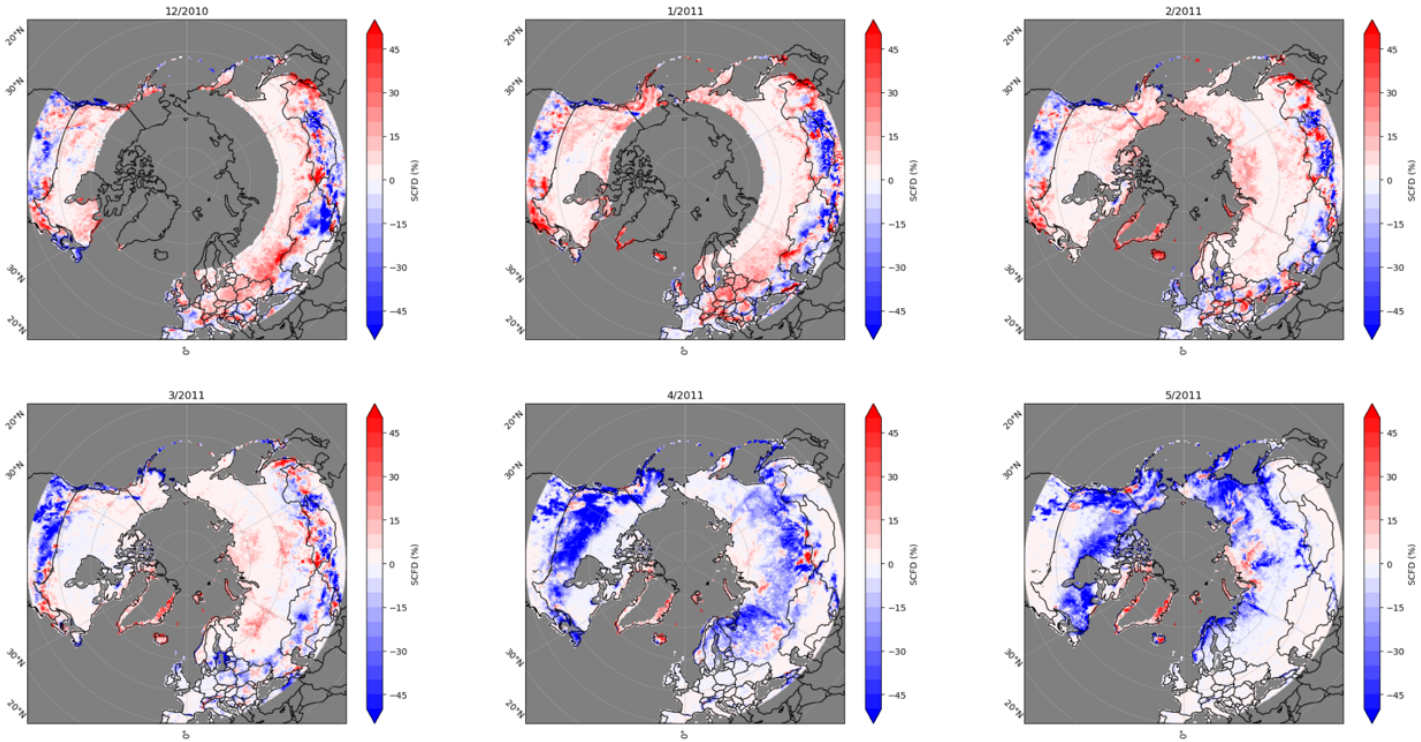


Mean temporal evolution of SCF for PFT7 and PFT8

Comparisons with ORCHIDEE

Snow fraction in ORCHIDEE

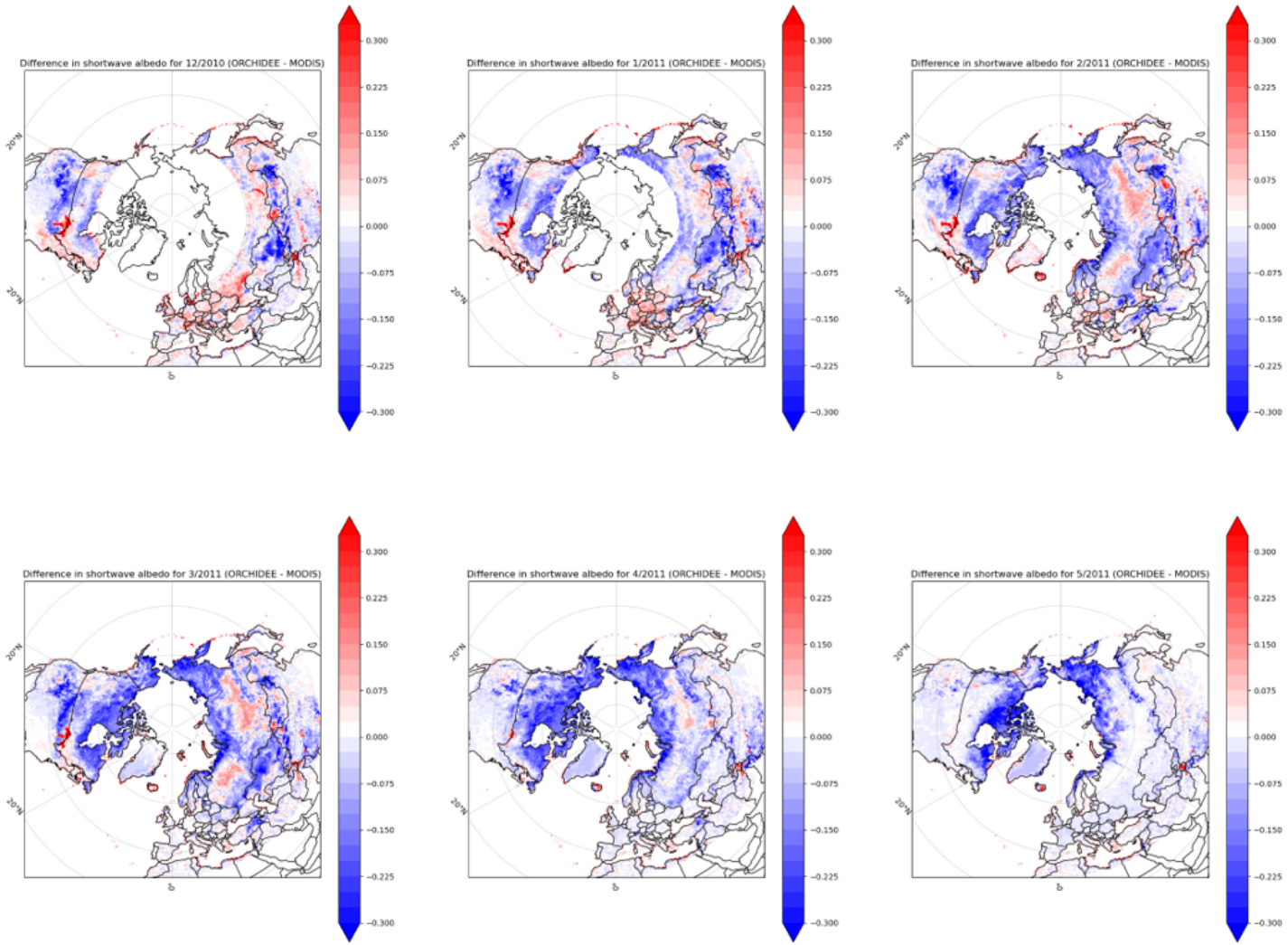
- *frac_snow* variable in ORCHIDEE corresponds to the snow cover fraction under the vegetation (should therefore correspond to the SCFG)



Winter 2010-2011 SCF differences between ORCHIDEE and MODIS (monthly averages)

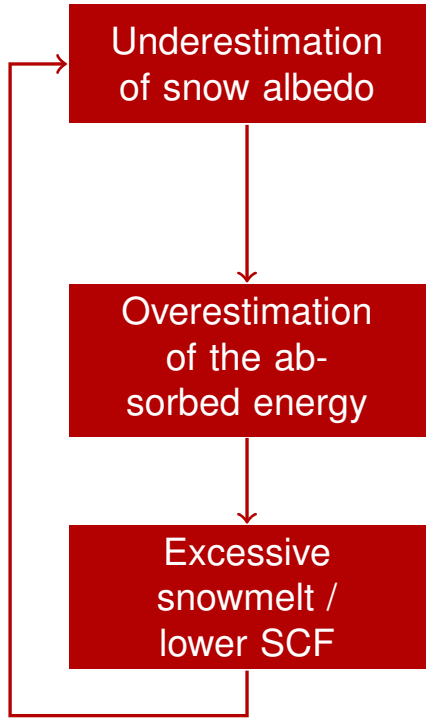
➙ Rushed snow disappearance at the end of winter in ORCHIDEE

Linked to the albedo?



Winter 2010-2011 shortwave albedo differences between ORCHIDEE and MODIS (monthly averages)

Feedback loop



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3) Optimization of the albedo parameters with ORCHIDAS

- Calculation of the albedo in ORCHIDEE v3
- Methodology
- Preliminary results

Albedo calculation in ORCHIDEE v3

$$albedo = frac_{veg}[(1 - frac_{snow,veg})alb_{veg} + frac_{snow,veg}alb_{snow,veg}] + frac_{nobio}[(1 - frac_{snow,nobio})alb_{nobio} + frac_{snow,nobio}alb_{snow,nobio}]$$

$$alb_{snow,veg} = \frac{\sum_{pft=1}^{15} frac_{max,pft} \times alb_{snow,pft}}{\sum_{pft=1}^{15} frac_{max,pft}}$$

$$alb_{snow,pft} = alb_{snow,aged,pft} + alb_{snow,dec,pft} \times e^{-age_{snow}/tcst_{snow}}$$

Proposed methodology

- Optimize the albedo parameters $alb_{snow,dec,pft}$ and $alb_{snow,aged,pft}$ for each PFT
  ➞ to do so, selection of sites representing each PFT with $frac_{snow}$ close to 1
- Optimize $frac_{snow}$

Criterions on the sites selection for multi-sites optimization

- Representing mostly only the chosen PFT (maximizing $frac_{max,pft}$)
- Having a maximum number of days for which the snow cover is big enough (over 95%) n_{snow}

Virtue function

$$V\left(frac_{max,pft}, n_{snow}\right) = \ln\left(n_{snow}\right) frac_{max,pft}$$

- Spatial representativity of the sites
- Small difference between the observed shortwave albedos of the chosen sites (monthly means)
- Flat regions (hills and mountains can impact the albedo)

Penalty functions

$$P_{i1}\left(x_{i-1}, \ldots, x_0\right) = \left(\min_{j=0,\ldots,i-1} \ln\left(1 + d\left(x_j, x_i\right)\right)\right)^{-1}$$

$$P_{i2}\left(x_{i-1}, \ldots, x_0\right) = \left(\max_{j=0,\ldots,i-1} \sum_{jan,\ldots,dec} \left|alb\left(x_i\right) - alb\left(x_j\right)\right|\right)$$

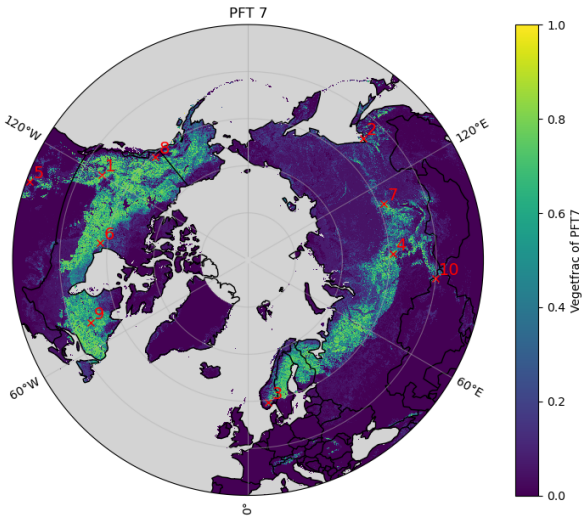
$$P_{i3} = slope$$

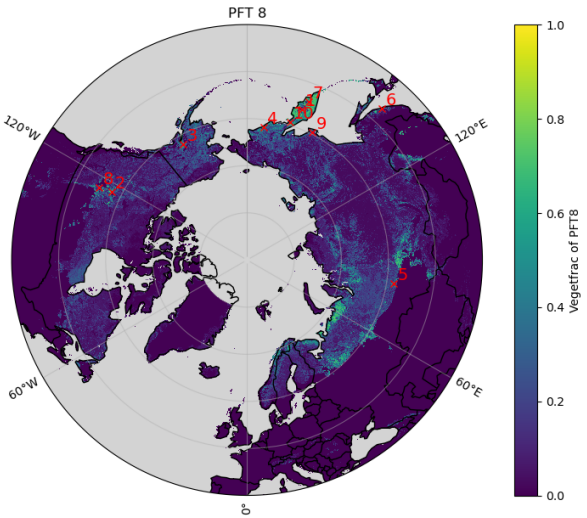
Desirability function and sites selection

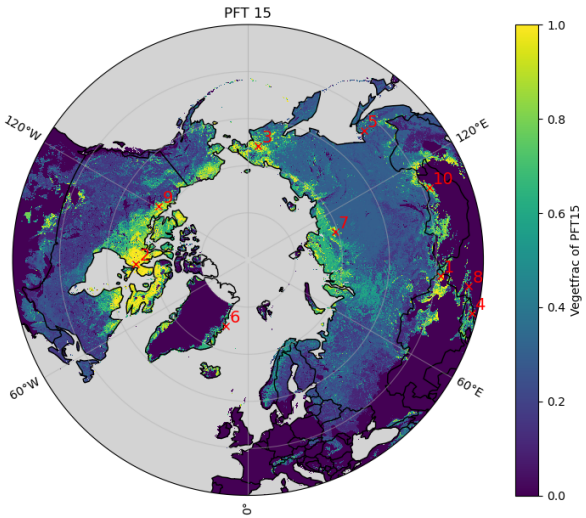
Desirability function

$$D_i\left(frac_{max,pft}, n_{snow}, x_{i-1}, \ldots, x_0\right) = V\left(frac_{max,pft}, n_{snow}\right) - k_j P_{i,k}\left(x_{i-1}, \ldots, x_0\right)$$

where V is the virtue function and $P_{i,k}$ are the three penalty functions

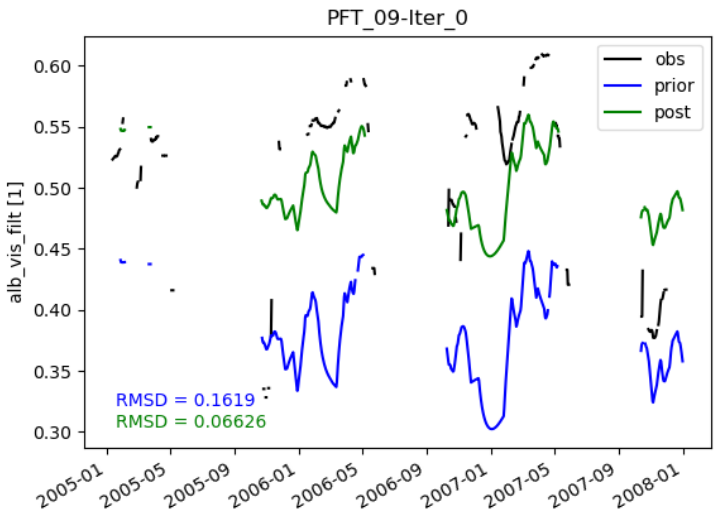


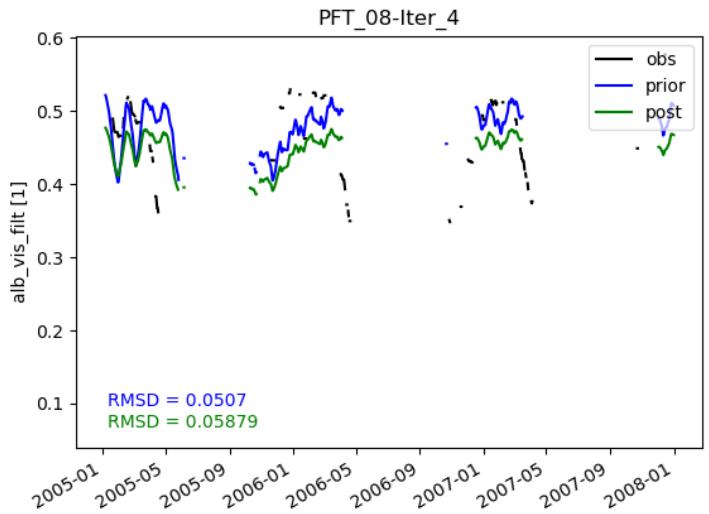


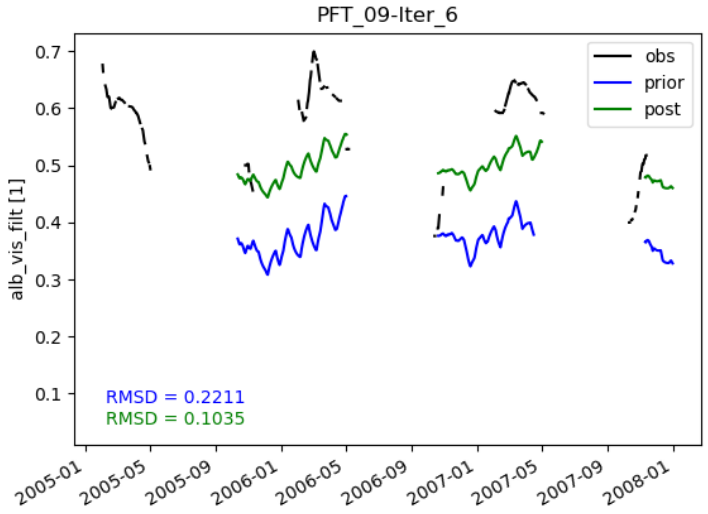


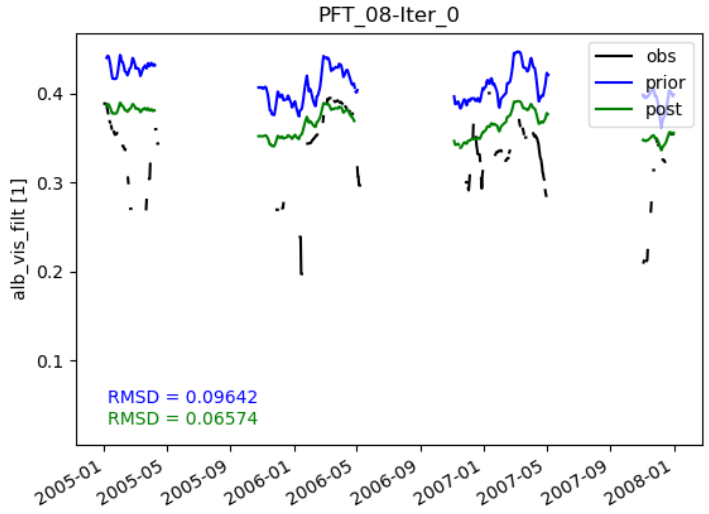
Preliminary results

Some examples of the optimization performed by ORCHIDAS for the visible albedo









Conclusions

Use of the ESA-CCI snow products to calibrate the snow albedo in ORCHIDEE

On-going work

Optimization of the albedo parameters for each PFT

- Development of a site selection algorithm
- First optimizations performed on sites
- Improvements of the albedo but still some issues to represent fully the observed behaviour (very site dependent)

Perspectives

- Optimization of the snow cover fraction calculated in ORCHIDEE
- Final simultaneous calibration of all the parameters (pre-tuned)
- Bigger scale tests (global simulations)
- Validation on longer time-series

Bibliographie I

 Solberg, R. et al. (Dec. 2021). « ESA CCI+ Snow ECV: Product User Guide, version 3.1 ». In.