WP5.6 Snow dynamics impacts on temperate/high latitude climate
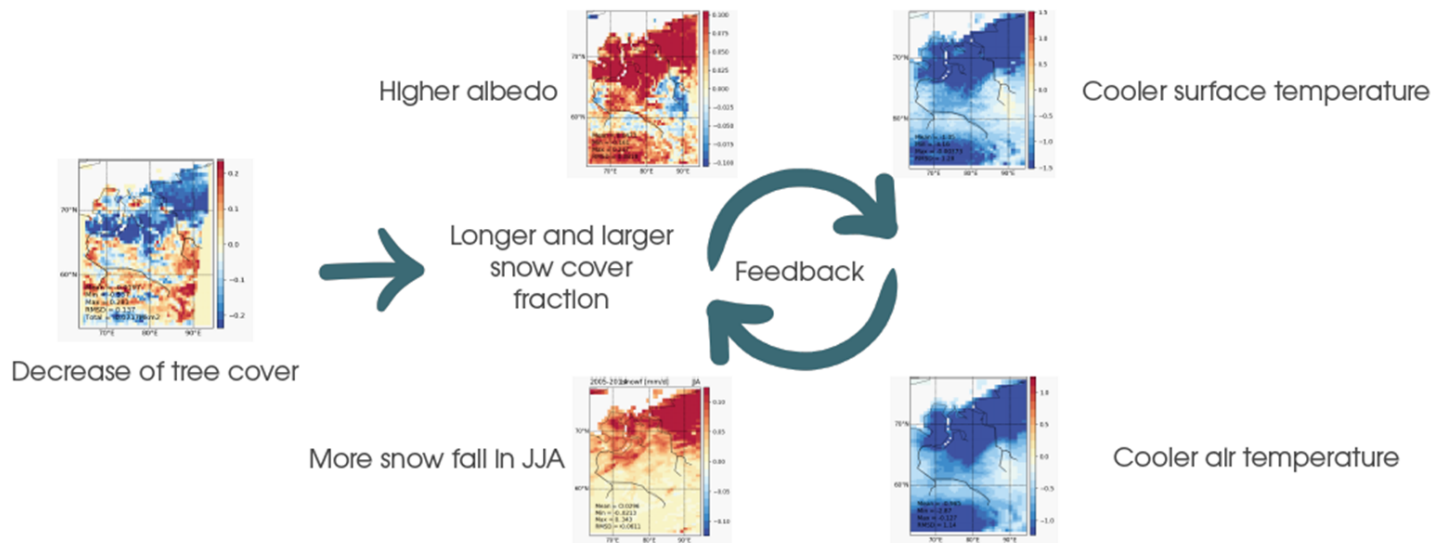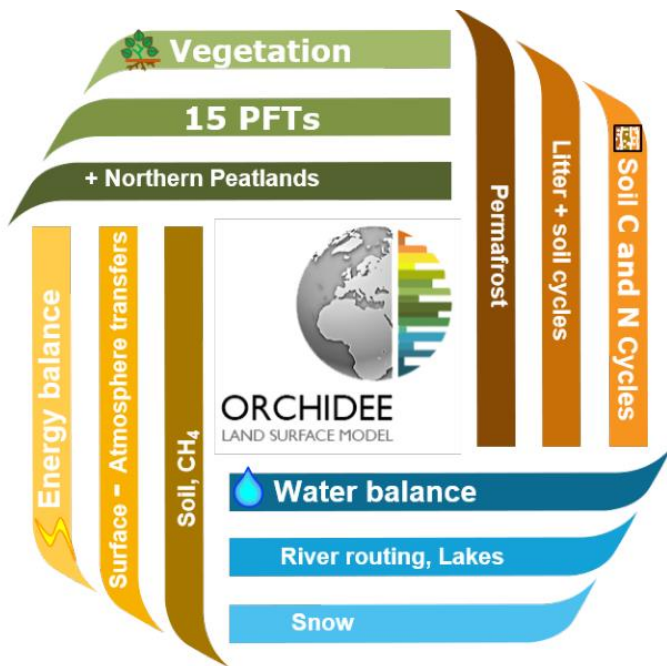
A. Cuynet, C. Ottlé, P. Peylin

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Improve our understanding and modelling of snow-vegetation-atmosphere feedback with the IPSL climate model (LMDZ-ORCHIDEE) and various ESA-CCI Products (especially Snow Products)

| PFT1: Bare Soil |
| PFT2: Tropical Evergreen |
| PFT3: Tropical Raingreen |
| PFT4: Temperate Needleleaf Evergreen |
| PFT5: Temperate Broadleaf Evergreen |
| PFT6: Temperate Broadleaf Summergreen |
| PFT7: Boreal Needleleaf Evergreen |
| PFT8: Boreal Broadleaf Summergreen |
| PFT9: Boreal Needleleaf Deciduous |
| PFT10: Temperate Natural Grassland (C3) |
| PFT11: Natural Grassland (C4) |
| PFT12: Crops (C3) |
| PFT13: Crops (C4) |
| PFT14: Tropical Natural Grassland (C3) |
| PFT15: Boreal Natural Grassland (C3) |

- ❑ Process-based model
- ❑ Energy, water, carbon and nitrogen budgets

More and more complex model → **Need to correctly represent the different processes and have correct sets of parameters**

Surface albedo in ORCHIDEE
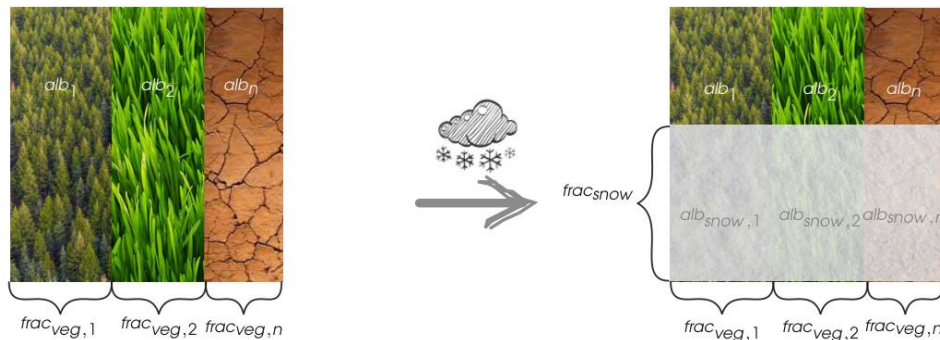
$$\underbrace{J(x)}_{\text{Misfit function}} = \frac{1}{2}[\underbrace{(\mathbf{H}(x) - y)^{\mathrm{T}}\mathbf{R}^{-1}(\mathbf{H}(x) - y)}_{\text{Observation term}} + \underbrace{(x - x_b)^{\mathrm{T}}\mathbf{B}^{-1}(x - x_b)}_{\text{Prior parameter term}}]$$

x: Values of the parameters to optimise
y: Set of observations
$\mathbf{H}$: Model outputs
x_b: Prior parameters

$\mathbf{R}$: Error covariance matrix on observations
$\mathbf{B}$: Error covariance matrix on parameters

DATA ASSIMILATION SYSTEM: parameter optimisation

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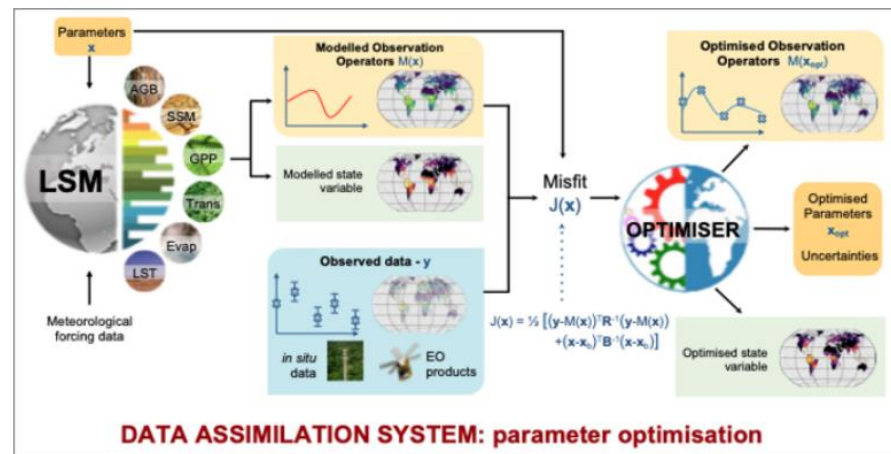
Progress on

WP5.6.1: CCI-SNOW PRODUCTS ANALYSIS

Snow Cover Fraction: Percentage of the ground covered by snow

Two types of SCF:

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

Determined from four optical sensors (different products) - almost 40 years of data combined

20 years of data with MODIS

(2000-2020) at 0.01° and daily resolution

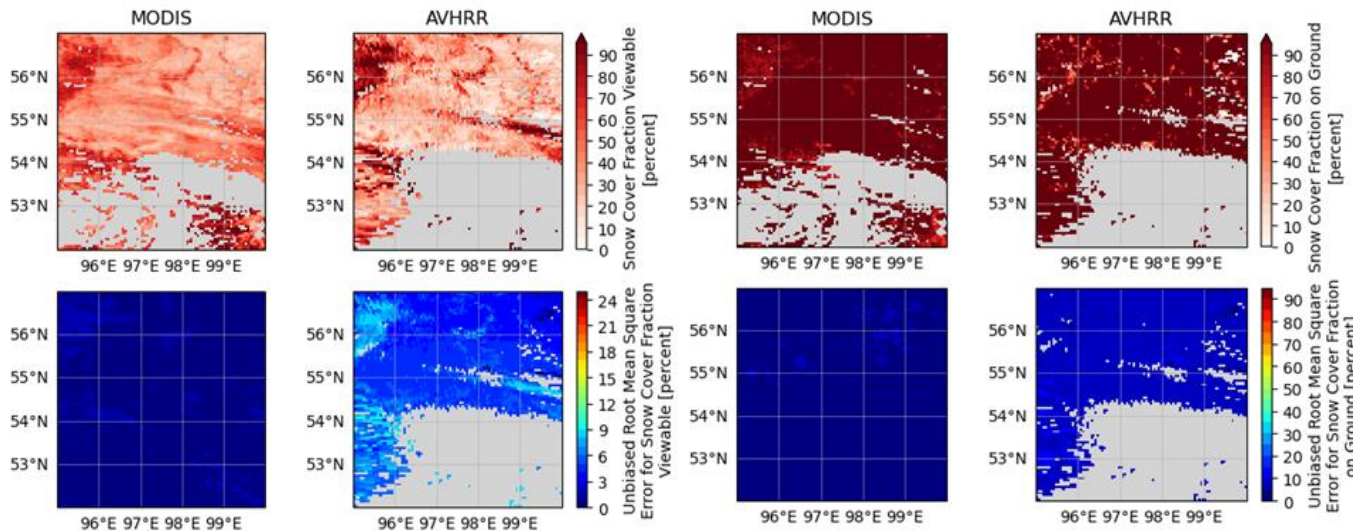**Snow Water Equivalent (SWE):** Height of the equivalent column of water (mm)

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SCFV from MODIS (upper left) and AVHRR (upper right), and the corresponding unbiased RMSE (lower panels) – day: 02/02/2010

SCFG from MODIS (upper left) and AVHRR (upper right), and the corresponding unbiased RMSE (lower panels) – day: 02/02/2010

Lower uncertainties in MODIS compared to AVHRR

Differences between the two products but similar SCF patterns

Selection of a 0,5° × 0,5° region in Siberia, covered by two PFTs (7: Boreal Needleleaf Evergreen and 8: Boreal Broadleaf Summergreen)

Spatial averaging of SCFV and SCFG for each day and PFT

→ Lower SCFV for PFT7 compared to PFT8
→ Closer values between the two PFTs for the SCFG

Emphasises the impact of the vegetation on the SCF
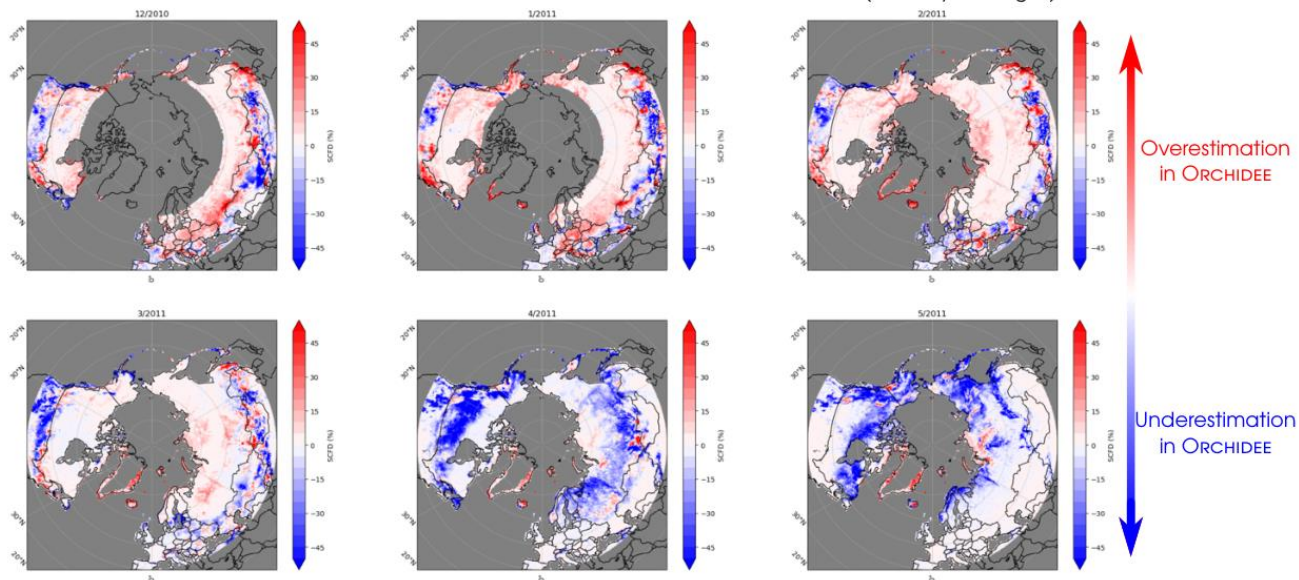
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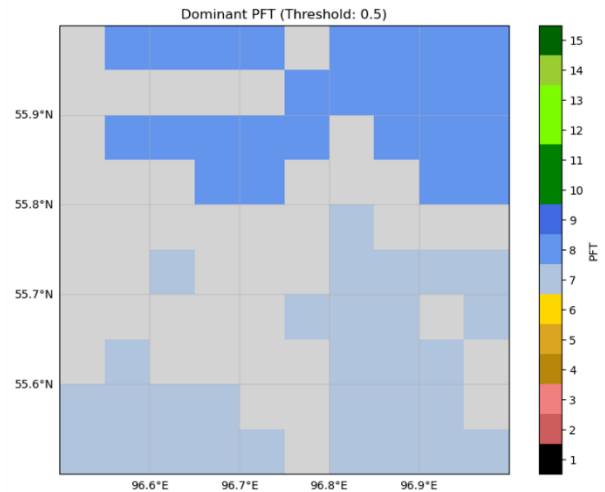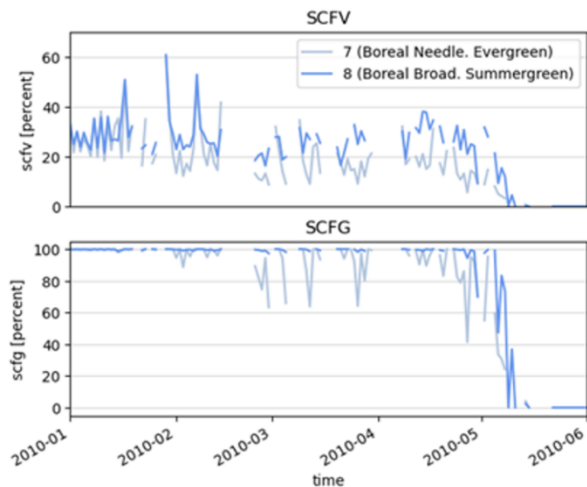
Snow fraction in ORCHIDEE
frac_snow variable in ORCHIDEE corresponds to the snow cover fraction under the vegetation (SCFG)

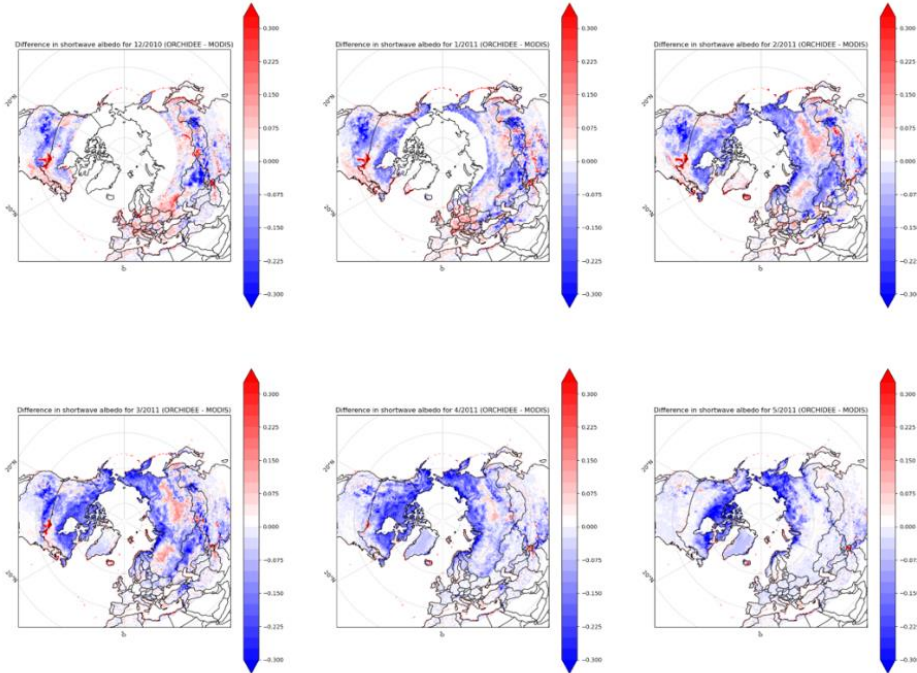Winter 2010-2011 SCF differences between ORCHIDEE and MODIS (monthly averages)
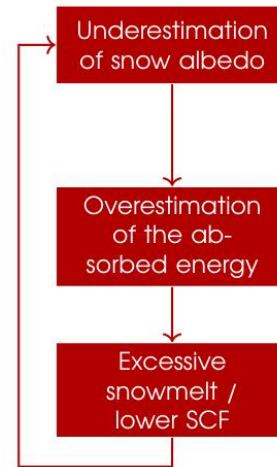
Overestimation in ORCHIDEE

Underestimation in ORCHIDEE

Overestimation during the accumulation period / underestimation during the ablation period

Monthly averaged shortwave albedo differences between ORCHIDEE and MODIS - from 12/2010 to 05/2011

Feedback loop

Underestimation of snow albedo

Overestimation of the absorbed energy

Excessive snowmelt / lower SCF

❑ Evaluation of the simulated snow cover dynamics (mass and extent) and snow albedo with prescribed climate forcing (ERA5)

❑ Identification of model biases

Improvement of the albedo and SCF necessary in the model

Progress on

WP5.6.2: ORCHIDEE MODEL DEVELOPMENTS

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Steps of the optimisation

Phase 1: Tuning of the snow albedo parameters

1) Selection of the most adapted sites: representativity of the vegetation and high snow cover fraction

Use of PFT maps and CCI Snow (SCFG)

2) Multi-site optimisation

Observed data: MODIS albedo

Phase 2: Tuning of the snow cover fraction parameters

New multi-site optimisation for the snow cover fraction parameters

Observed data: MODIS albedo, CCI Snow SCF and SWE

Optimised snow albedo and snow cover fraction parameters for each PFT

➔ better estimates of winter albedo and SCF, improvements in the energy budget

Steps of the optimisation

Phase 1: Tuning of the snow albedo parameters

Phase 2: Tuning of the snow cover fraction parameters

Optimised snow albedo and snow cover fraction parameters for each PFT

Performed on ORCHIDEE v3 – the methodology will be applied to the last version of ORCHIDEE with the following features:

- **New snow scheme**[1]
- **Updated scheme for the calculation of the vegetation albedo**
- **New PFT maps** derived from the ESA CCI MRLC project[2]

[1] Charbit et al., 2024, in press
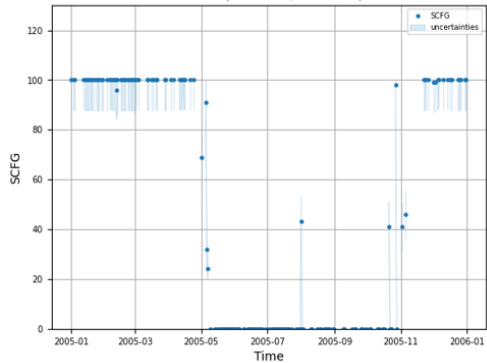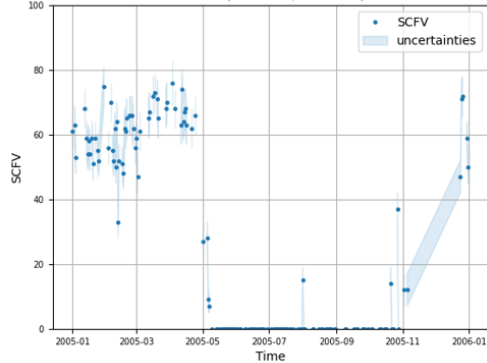[2] PFT V3.0 product, Harper et al., 2022

THANK YOU

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Point : (54.52°N,-77.88°E)
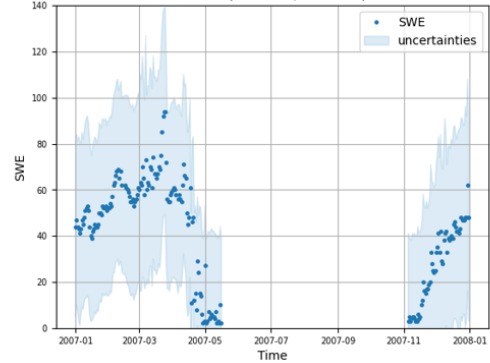

Point : (54.52°N,-77.88°E)

Point : (54.52°N,-77.88°E)

Time series of MODIS SCFG [%], MODIS SCFV [%] and SWE [mm] with the provided uncertainties at a selected point in Siberia (54.52° N, -77.88° E)
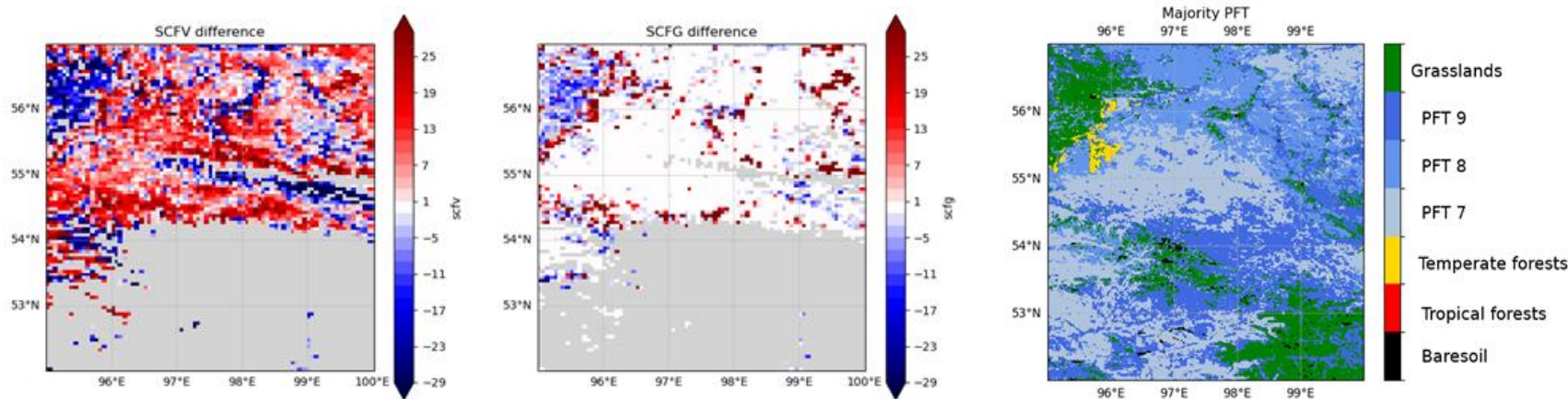
Consistency between the different time series

Large uncertainties for SWE

Differences between MODIS and AVHRR SCFV (left) and SCFG (right) – date: 02/02/2010

Most common PFT per pixel in the studied region extracted from the ORCHIDEE PFT map derived from the CCI – Medium Resolution Land Cover dataset

Differences between MODIS and AVHRR seem to be both related to latitude and to the dominant PFT map
→ *Probably related to the different characteristics of MODIS and AVHRR sensors/orbital parameters and post-treatment methods*

Snow Cover Fraction: Percentage of the ground covered by snow

Two types of SCF:

• *Viewable (SCFV): as seen from space*

• *Ground (SCFG): calculated by correcting the masking effect of the canopy layer*

Determined from four optical sensors (different products) - almost 40 years of data combined

20 years of data with MODIS

(2000-2020) at 0.01° and daily resolution

Snow Water Equivalent (SWE): Height of the equivalent column of water (mm)

One product (combination of different sensors)

Spatial resolution: 0,1° / Temporal resolution: daily

Only available for the Northern hemisphere and no data for mountaineous areas

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