

climate change initiative

→ CLIMATE MODELLING USER GROUP

WP5.6 Snow dynamics impacts on temperate/high latitude climate

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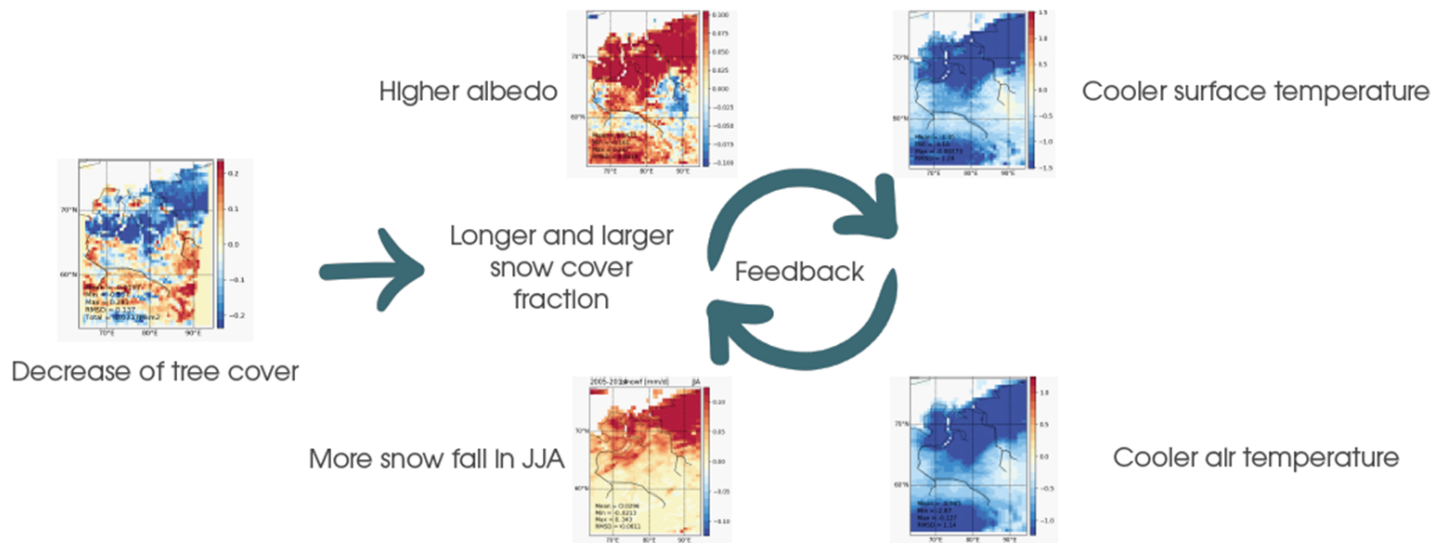


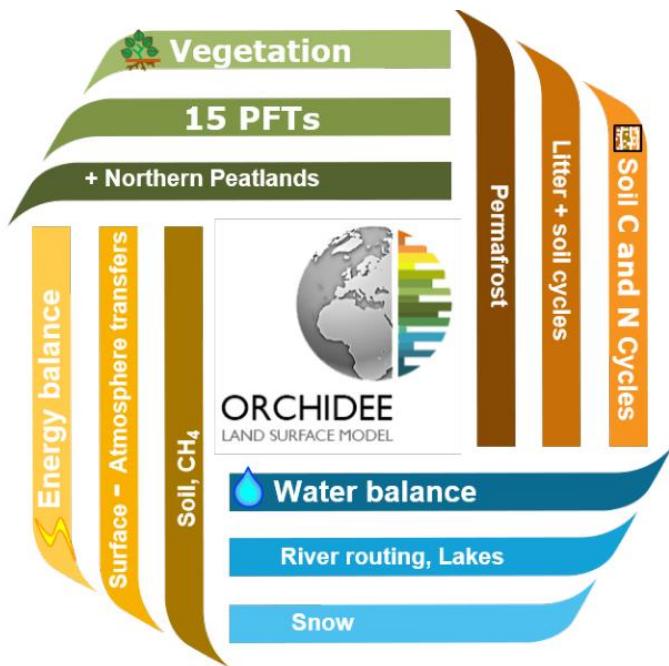


Main goal



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)





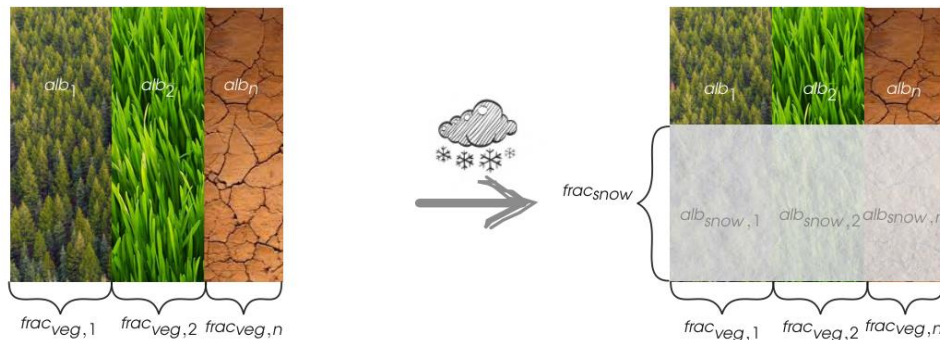
PFT1: Bare Soil
PFT2: Tropical Evergreen
PFT3: Tropical Raingreen
PFT4: Temperate Needleleaf Evergreen
PFT5: Temperate Broadleaf Evergreen
PFT6: Temperate Broadleaf Summergreen
PFT7: Boreal Needleleaf Evergreen
PFT8: Boreal Broadleaf Summergreen
PFT9: Boreal Needleleaf Deciduous
PFT10: Temperate Natural 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



$$J(x) = \frac{1}{2} \left[\underbrace{(\mathbf{H}(x) - y)^T \mathbf{R}^{-1} (\mathbf{H}(x) - y)}_{\text{Observation term}} + \underbrace{(x - x_b)^T \mathbf{B}^{-1} (x - x_b)}_{\text{Prior parameter term}} \right]$$

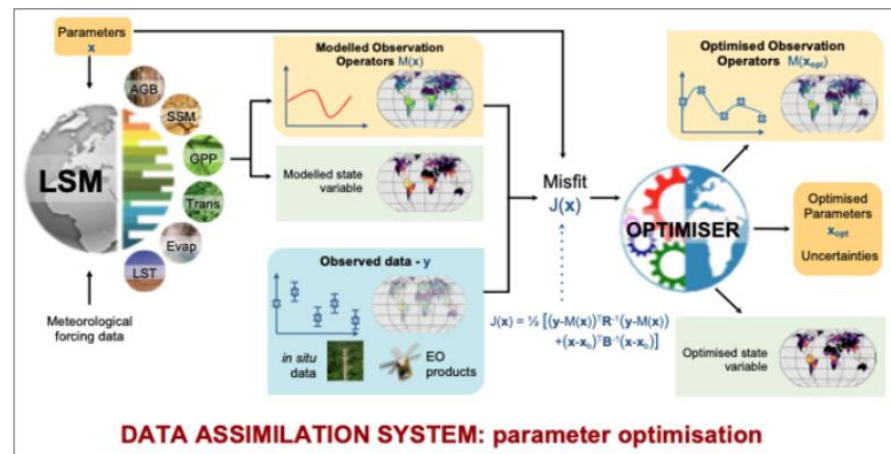
Misfit function

Observation term

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





Progress on

WP5.6.1: CCI-SNOW PRODUCTS ANALYSIS





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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)



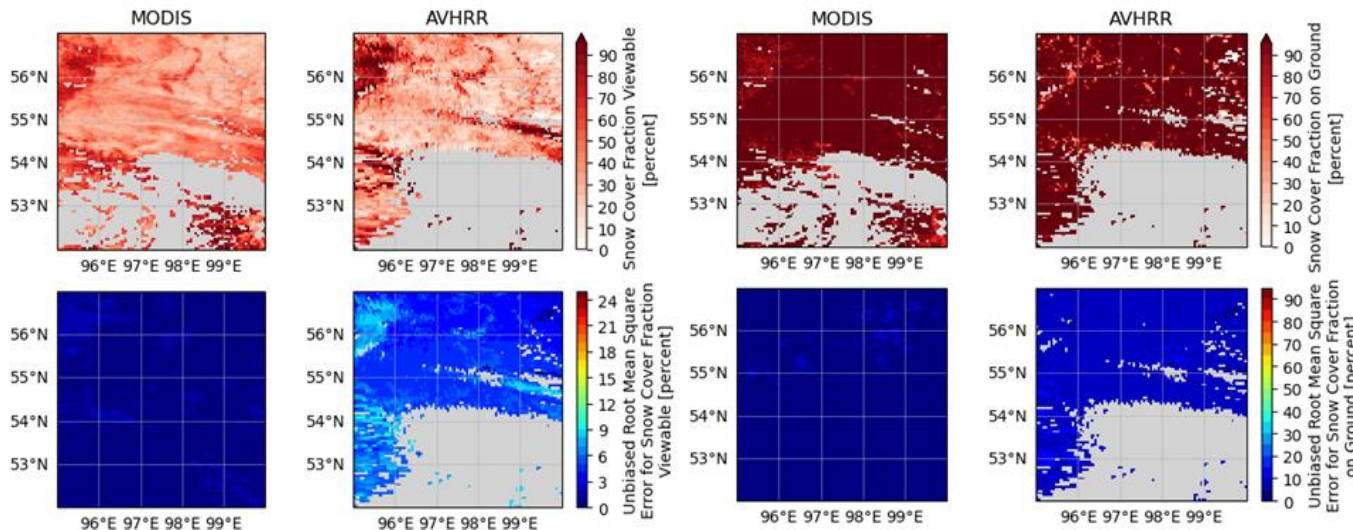
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MODIS SCF vs AVHRR SCF



Lower uncertainties in MODIS compared to AVHRR

Differences between the two products but similar SCF patterns

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





Influence of vegetation type on snow dynamics

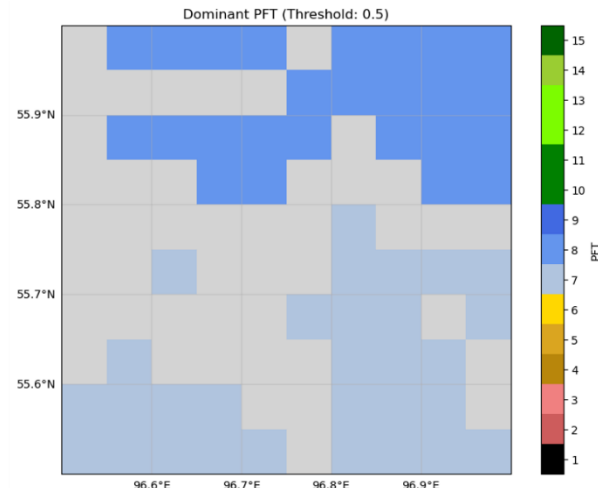
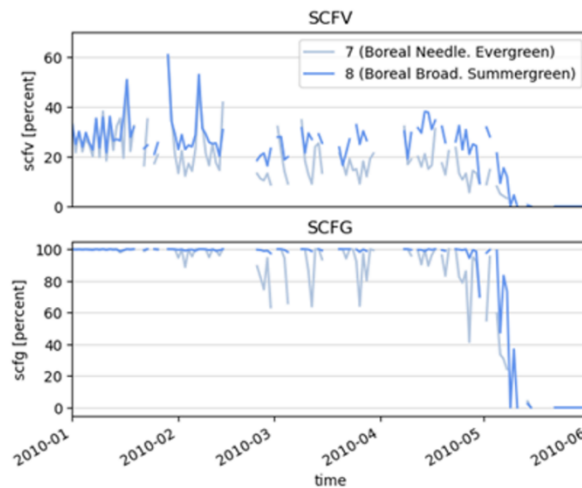


Selection of a $0,5^\circ \times 0,5^\circ$ region in Siberia, covered by two PFTs (7: Boreal Needleleaf Evergreen and 8: Boreal Broadleaf Summergreen)

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





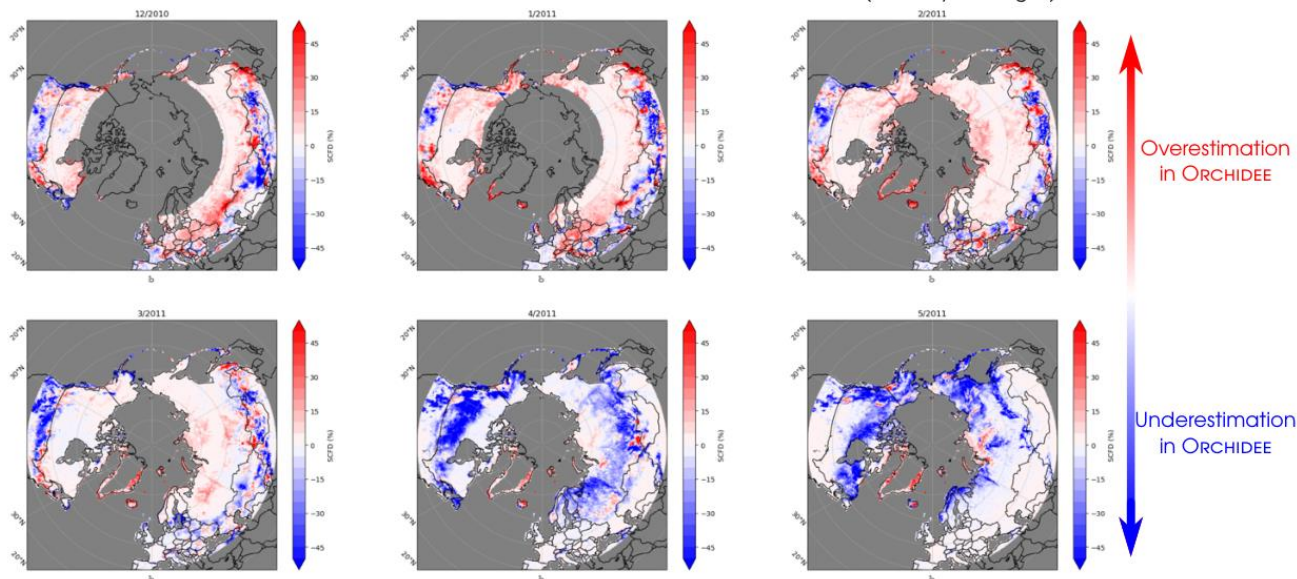
Comparison with ORCHIDEE (SCF)



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)

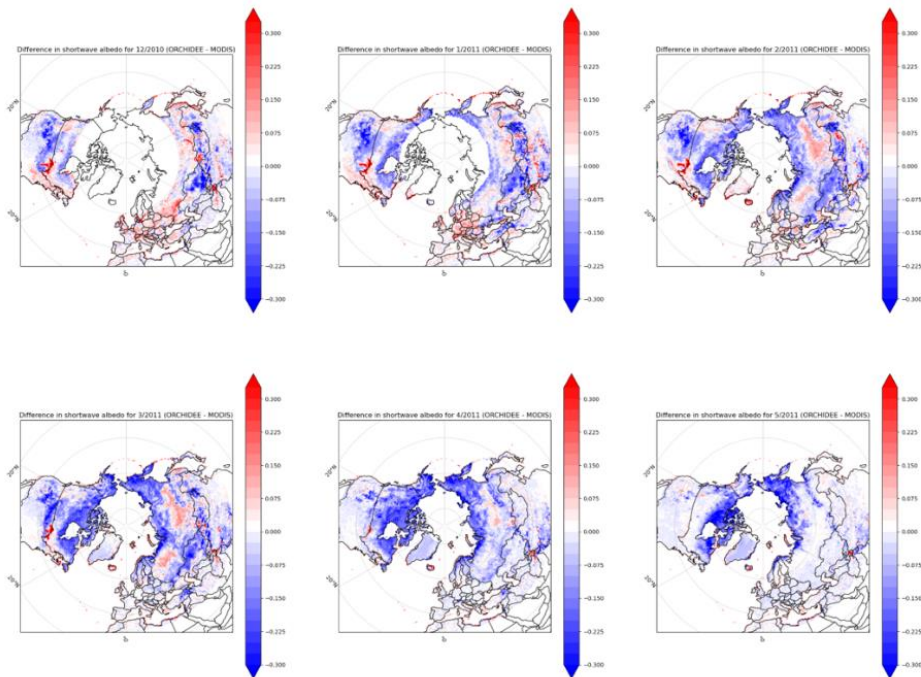


Overestimation during the accumulation period / underestimation during the ablation period

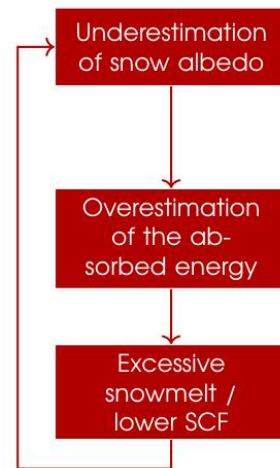




Comparison with ORCHIDEE (albedo)



Feedback loop



- ❑ 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

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





Progress on

WP5.6.2: ORCHIDEE MODEL DEVELOPMENTS





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 scheme¹**
- **Updated scheme for the calculation of the vegetation albedo**
- **New PFT maps derived from the ESA CCI MRLC project²**

¹ Charbit et al., 2024, in press

² PFT V3.0 product, Harper et al., 2022



THANK YOU

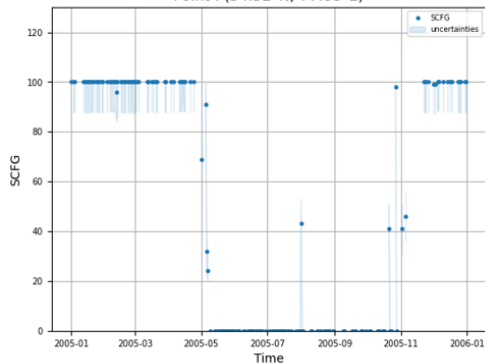




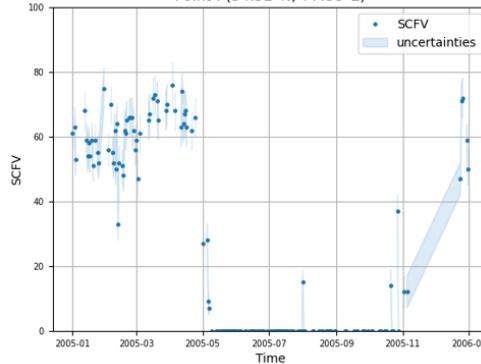
Site evolution of SCF and SWE



Point : (54.52°N,-77.88°E)

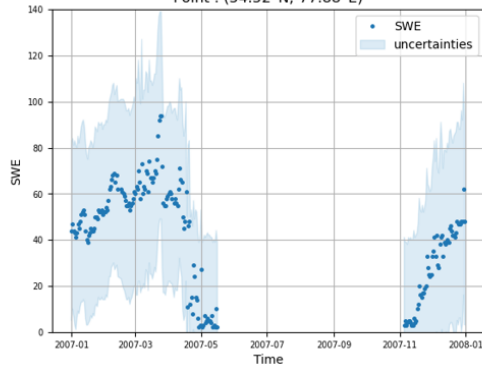


Point : (54.52°N,-77.88°E)



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)

Point : (54.52°N,-77.88°E)



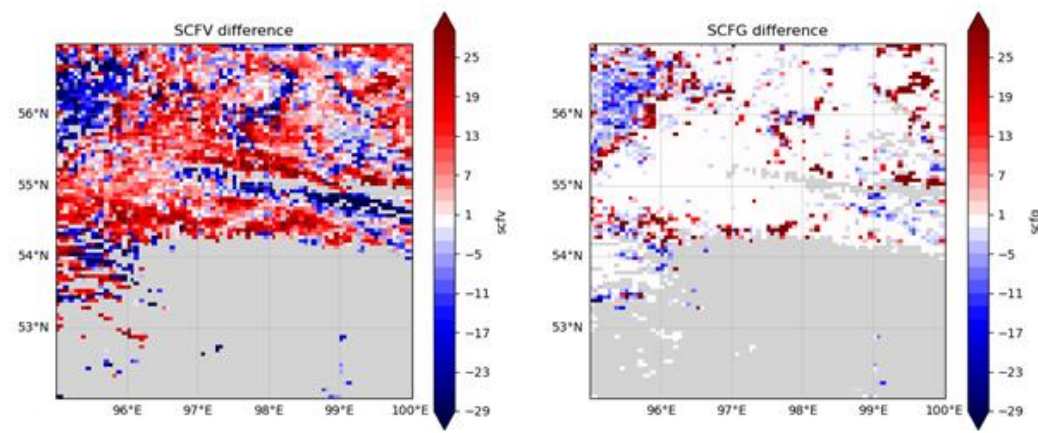
Consistency between the different time series

Large uncertainties for SWE

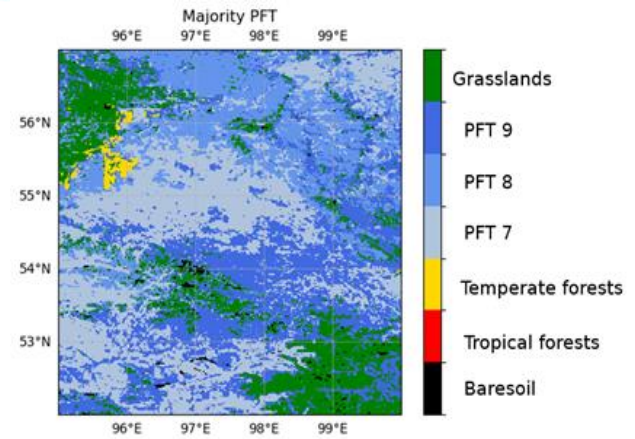




MODIS SCF vs AVHRR SCF and impact of PFT



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





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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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