UNIVERSITÄT BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

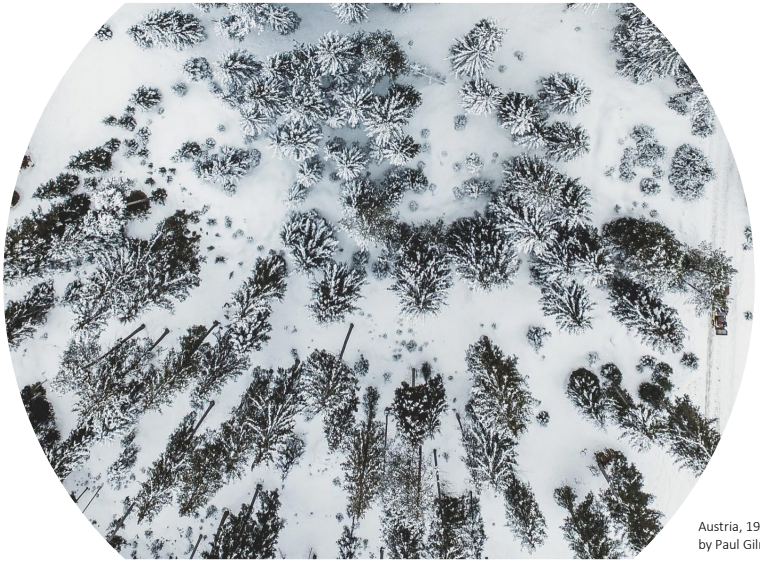
Less White: Decreasing Alpine Snow Cover Derived From A 40-year AVHRR Snow Climatology

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08.02.2023, EARSeL, Bern

Snow in forests



Austria, 19.03.2018
by Paul Gilmore

Snow in forests

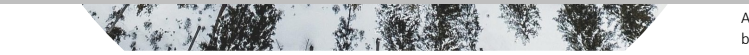


PART I

AVH_FSCv1 dataset (1981 - 2021)
Data, Methods, Validation & L2/L3 Products

PART II

Intra- and inter-annual changes in FSC
Spatial-temporal patterns of SCA
Impact of elevation-dependent warming on SCMD/SCD and SOS/LOS

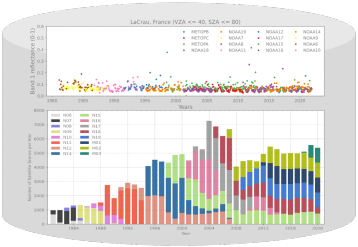


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PART I: *AVH_FSCv1* dataset

- Consistent RSGB/UniBe AVHRR LAC L1C v04 dataset (1981-2021, dated 04/2021)
- Improved prob. cloud masking (NWC/PPS v2021.1, SMHI)
- Pixel-scale, AVHRR-adjusted parameterization of SCAMOD Model (Metsämäki et al., 2005, 2012, 2015, Salminen et al., 2013, Weber et al., 2021)

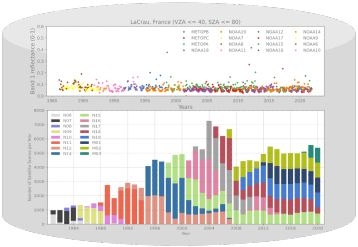
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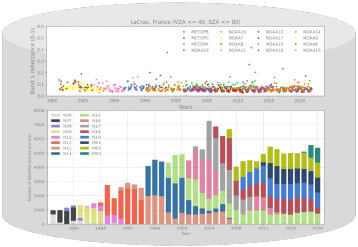
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Adapted SCAMOD Model

Volume scattering — Surface scattering

$$\rho_{\lambda,\mathrm{obs}}(FSC) = \overbrace{(1-t_\lambda^2) * \rho_{\lambda,forest}}^{\text{Volume scattering}} + \overbrace{t_\lambda^2 * [FSC * \rho_{\lambda,snow} + (1-FSC) * \rho_{\lambda,ground}]}^{\text{Surface scattering}}$$

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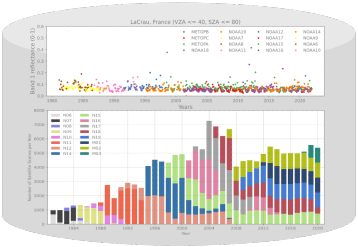
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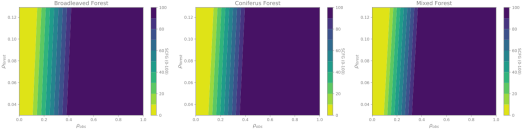
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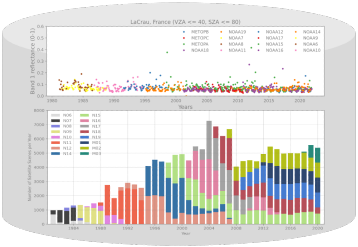
$$\rho_{\lambda,\mathrm{forest}} = \frac{\rho_{\lambda,\mathrm{obs}} - t_\lambda^2 * \rho_{\lambda,\mathrm{ground}}}{1-t_\lambda^2}, \qquad \text{when FSC} = 0\%$$

Sensitivity study for main forest types in Switzerland:



- Increasing $\rho_{\lambda,\ \mathrm{forest}}$ results in lower FSC
- Varying $\rho_{\lambda,\ \mathrm{forest}}$ causes difference of up to 30% in SCFG

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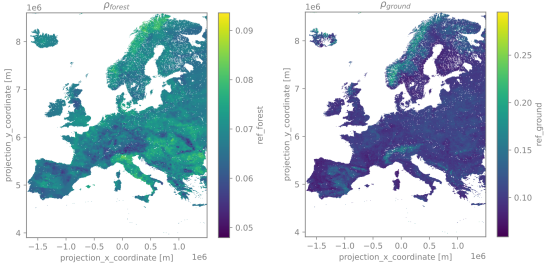
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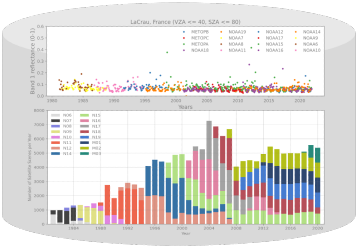
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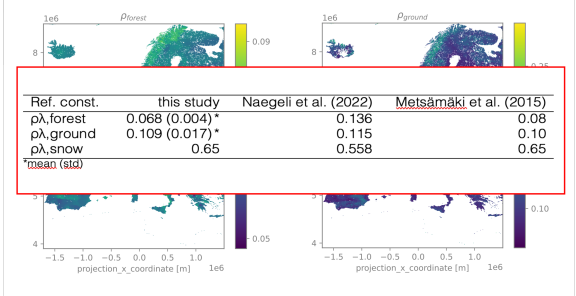
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Ref. const.	this study	Naegeli et al. (2022)	Metsämäki et al. (2015)
ρλ,forest	0.068 (0.004)*	0.136	0.08
ρλ,ground	0.109 (0.017)*	0.115	0.10
ρλ,snow	0.65	0.558	0.65

*mean (std)

AVH_FSCv1 dataset

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- Improved prob. cloud masking (NWC/PPS v2021.1, SMHI)
- Pixel-scale, AVHRR-adjusted parameterization of SCAMOD Model (Metsämäki et al., 2005, 2012, 2015, Salminen et al., 2013, Weber et al., 2021)
- End-to-end uncertainty estimation following ESA CCI+ Snow Project (Salberg et al., 2022)
- Independent validation using 30 m Landsat-derived snow cover maps (V. Premier, EURAC 2022)

Table 1: Summary validation statistics averaged for all satellites of the validation data set (i.e., MetOp-A, MetOp-B, NOAA-11, -12, -14, -15, -16-, -17, -18, -19) for SCFG (SCFV), respectively. Results are shown for different land cover types (i.e., forests, open areas), landforms (mountain, plain), all (land cover types and landforms), and limited to a viewing zenith angle (VZA) < 40 degree, which is known to increase the quality of the pixel information.

	All	Forested	Open Areas	Mountain	Plain	VZA < 40
RMSE	26.249 (30.602)	27.612 (33.806)	25.372 (28.448)	26.959 (24.4)	25.654 (34.856)	21.322 (30.687)
Unbiased RMSE	26.207 (26.4)	27.025 (27.033)	24.68 (25.553)	26.956 (22.665)	25.474 (28.02)	20.678 (25.268)
Bias	-1.482 (-15.477)	5.661 (-20.3)	-5.885 (-12.504)	0.426 (-9.038)	-3.04 (-20.73)	-5.201 (-17.413)
Correlation Coefficient	0.811 (0.784)	0.802 (0.759)	0.831 (0.81)	0.78 (0.827)	0.827 (0.76)	0.88 (0.803)

- *AVH_FSCv1* dataset (1981 – 2021) soon openly available

Weber, H., Naegeli, K. and Wunderle, S. (2021): Impact of forest canopy parameterization on space-borne snow on ground detection. IEEE International Geoscience and Remote Sensing Symposium, IEEE, DOI: 10.1109/IGARSS47720.2021.955

AVH_FSCv1 dataset

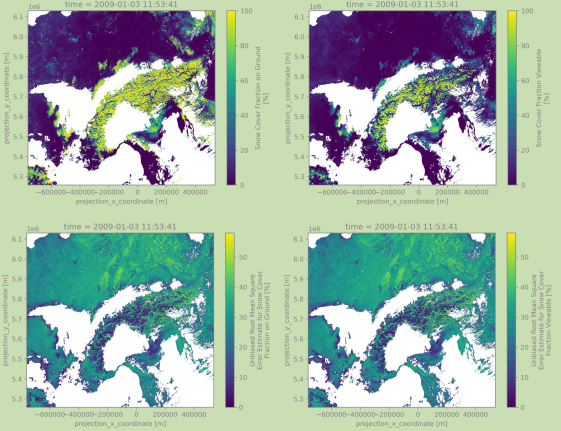
FACTSHEET: *AVH_FSC-v1* product

OVERVIEW:

- Fractional snow cover product for GCOS Switzerland by RSGB/University of Bern
- 1 km, daily *AVH_FSC-v1* Product (Level-2)
- 1 km, 10-day *AVH_FSC10-v1* Product (Level-3)
- Temporal extent: 1981 – 2021
- Spatial extent: COSMO-1 Ensemble Forecast

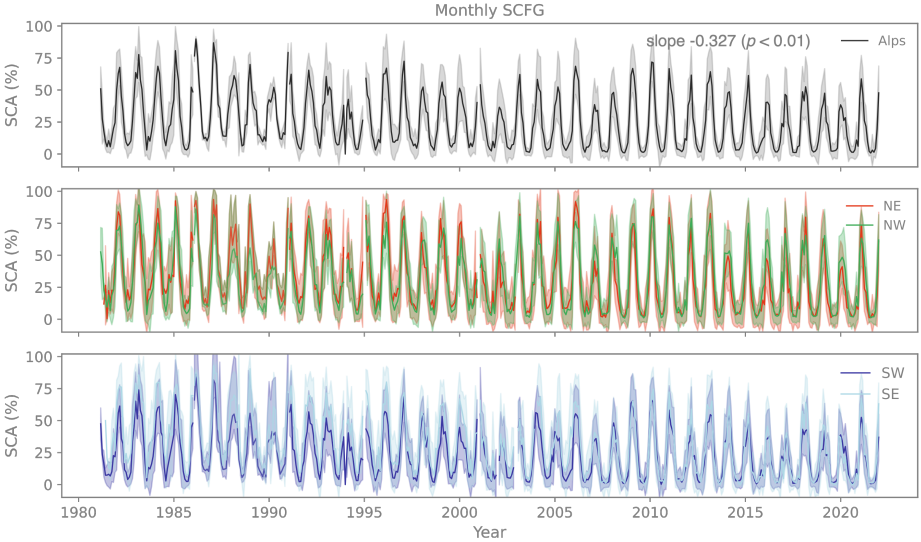
TECHNICAL DETAILS:

- Data: 1 km, daytime swath-based AVHRR LAC L1C v04 (~74.000 scenes)
- Data source: RSGB/University of Bern
- Two snow mask layers:
  - SCFG: Snow Cover Fraction Ground
  - SCFV: Snow Cover Fraction Viewable
- Pixel-wise uncertainty estimate
- Quality and condition flags (i.e., forest, cloud, vza < 40°)
- Detailed Attributes (i.e., time, proj4, satellite, 3A flag)
- File type: Level-2 and Level-3
- Format: NetCDf CF-1.9

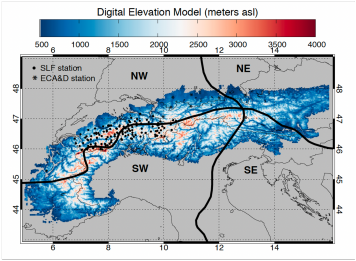


Weber, H. & Wunderle, S. (2022). Fractional Snow Cover Timer Series (1981 - 2021), Techn. Report, GCOS Switzerland, 2022

Inter-annual changes of SCA time series

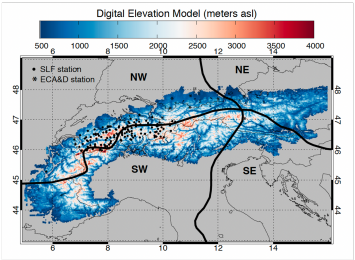


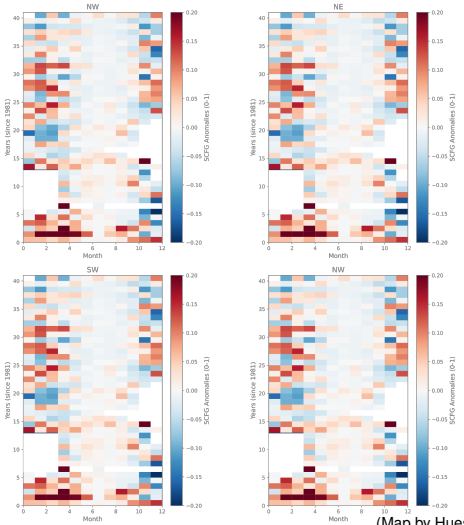
Monthly Intra-annual variation



(Map by Huesler et al., 2014)

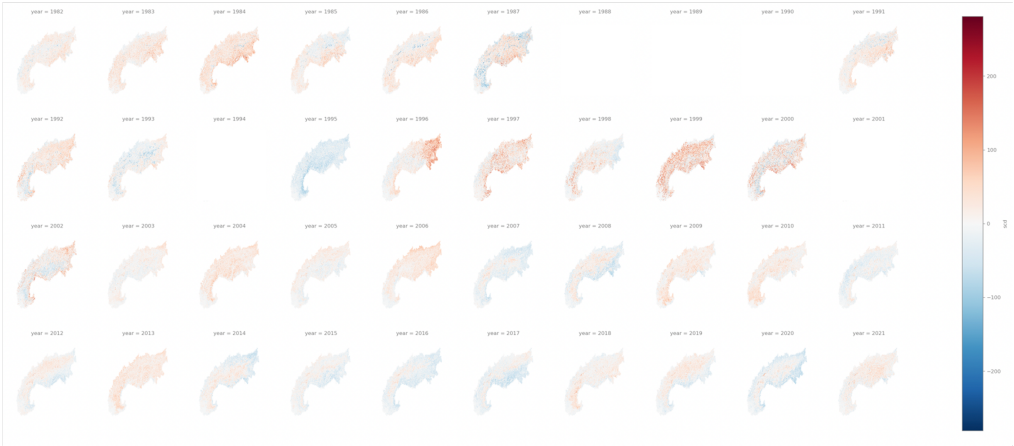
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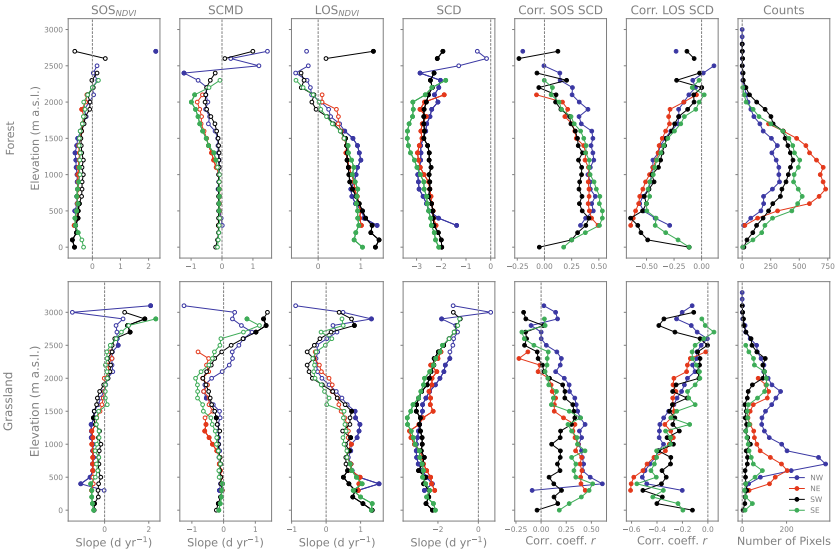


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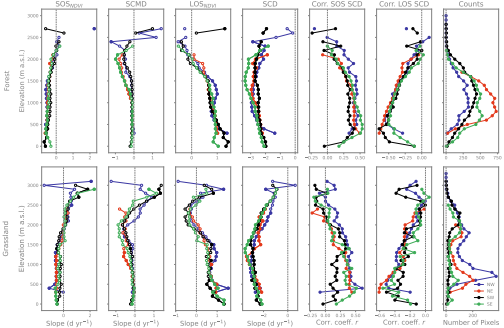
Spatial variation of annual SCD anomalies



Impact of elevation-dependent warming on SCD/SOS



Impact of elevation-dependent warming on SCD/SOS



- SOS trends occur earlier in the Alps with -0.46 $\mathrm{d\,yr^{-1}}$ for SW to -0.57 $\mathrm{d\,yr^{-1}}$ for NW for forest and grassland zones at elevations < 1500 m, resulting in an increased vegetation period of 0.71 $\mathrm{d\,yr^{-1}}$ to 0.96 $\mathrm{d\,yr^{-1}}$ (LOS)
- SCD trends are highly significant ($p < 0.05$) with largest decreasing trends in the middle elevation zone (1000 < h < 2000 m) of about -2.6 $\mathrm{d\,yr^{-1}}$ for SW up to -3.22 $\mathrm{d\,yr^{-1}}$ SE, but SCMD trends are only significant for SE and NE
- Inter-annual variation in trends is overall larger for grasslands compared to forests and is most pronounced for LOS < 1500 m and the SCD in the middle elevation zones

Conclusion and outlook

- Novel consistent canopy-corrected 1 km *AVH_FSCv1* Level 2 & 3 dataset (1981 – 2021) incl. pixel-wise uncertainty estimates
  - Developments underpinned the importance of representative model parameters and sensor-specific adaptation
  - Pixel-based parameterization approach allows temporal-varying reflectance maps
- Results highlighted
  - The importance of a long-term FSC time series for climatological studies
  - Overall significant decrease of SCA Alps: slope -0.327 ($p<0.01$)
  - Largest decreasing SCD trends in the middle elevation zone up to -3.22 d yr^{-1} and overall increased vegetation period of up to 0.96 d yr^{-1}
- Outlook
  - *AVH_FSCv1* dataset (1981 – 2021) soon openly available

Thank you for your attention.

— Acknowledgement: This study is funded by MeteoSwiss in the framework of GCOS Switzerland.

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