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18 Remote Sensing of the Spheres

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18. Remote Sensing of the Spheres

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Swiss Commission for Remote Sensing
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18.1

InSAR-based mobile mapping of surface displacements from UAV/car-borne platforms

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While current stationary terrestrial radar systems used for the measurement of surface displacements are bound to relatively high frequencies (many of them operating at Ku- or X-band) to ensure a good cross-range resolution, an L-band SAR system, when operated in car-borne mode (or UAV-borne mode), can still achieve a high cross-range resolution on the order of less than 0.5 m up to few meters. The cross-range resolution mostly depends on whether the full range-varying length of the synthetic aperture is obtained for the entire image, which again depends on geometric constraints imposed by the road (car-borne mode), possible flight tracks (airborne/UAV) and the topography. An important advantage and somewhat complementary property to the high-frequency stationary systems is the reduced temporal decorrelation at L-band. While the sensitivity to line-of-sight displacements is lower, the longer wavelength at L-band permits to acquire longer interferometric time series also in natural terrain, where the decorrelation time at Ku-band can be in the order of minutes or less. VTOL UAVs are agile airborne platforms that allow flexible planning and realization of sensor trajectories that are tailored to a specific application. E.g., linear repeat-pass sensor trajectories within a valley can be flown to assess the line-of-sight displacement of a valley slope, irrespective of the direct accessibility of the terrain on the ground. A repeat-pass interferometric campaign has been conducted with the GAMMA L-band SAR mounted on the VTOL UAV Scout B1-100 by Aeroscout GmbH (see Fig. 1). We also present a repeat-pass interferometric phase measurements of the line-of-sight phase component induced by the flow velocity of an alpine glacier obtained in fall 2018 with the GAMMA L-band SAR. In this demonstration case, the GAMMA L-band SAR system is operated in a car-borne mode [6,7]: several repeat-pass SAR acquisitions of an alpine glacier are taken from a car driven along a slightly curved section of a mountain road in central Switzerland. The car-borne SAR data is focused directly to map coordinates involving a digital elevation model by using a time-domain back-projection (TDBP) approach [1-3] & [4,5]. These geocoded complex SAR images then allow to directly form differential interferograms in map coordinates. The feasibility of repeat-pass interferometry using the novel GAMMA L-band SAR on an agile mobile mapping platform is successfully demonstrated with several data examples (see Fig.2 & and 3 and their captions).

Figure 1: GAMMA L-band SAR on Aeroscout's VTOL UAV Scout B1-100, equipped with a Honeywell HGuide n580 INS/GNSS navigation system, at the test site Wolfenschiessen, Switzerland.

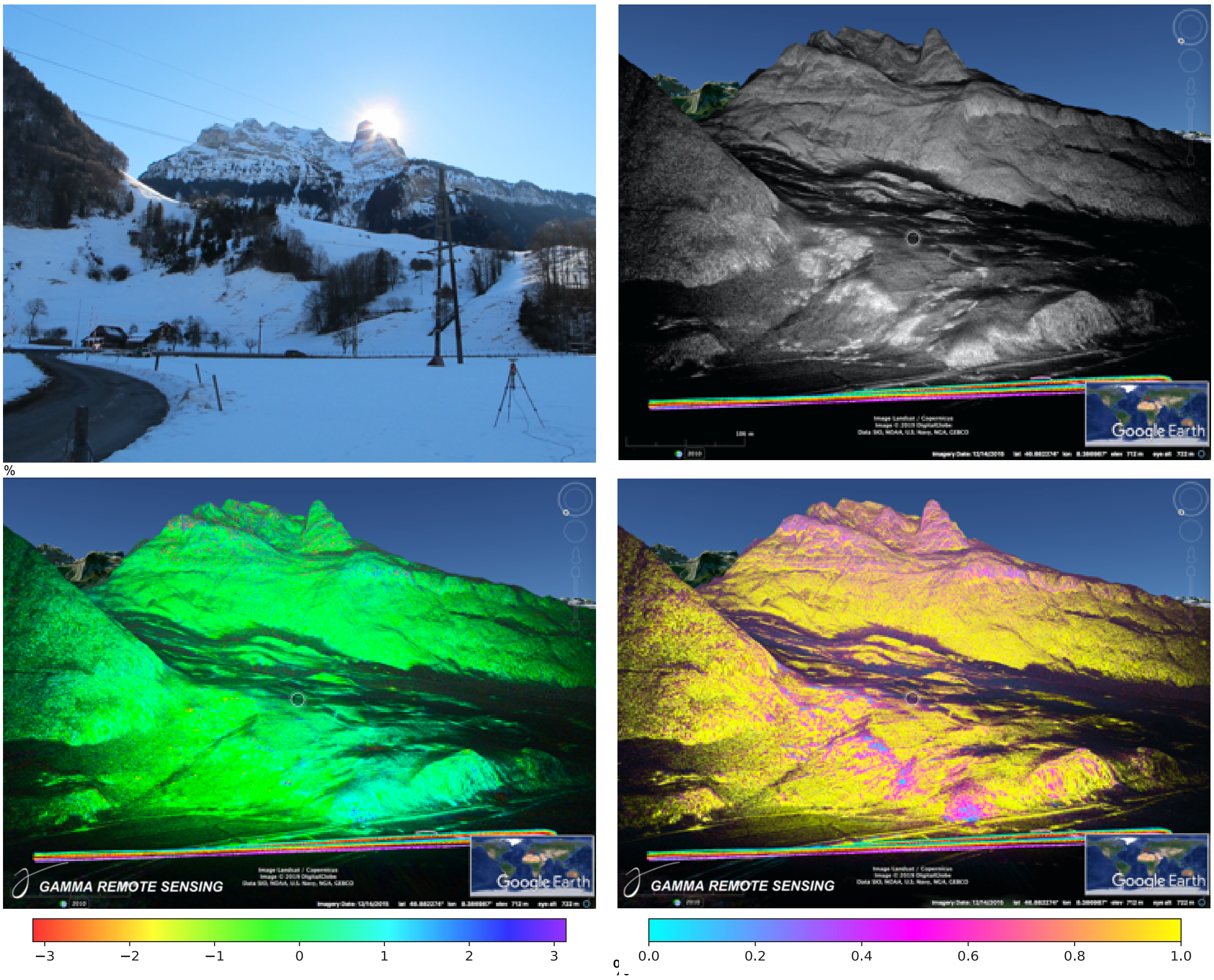

Figure 2: Top left: Area of interest on the campaign day. On the lower right of the photograph, the local GNSS reference station is situated to obtain a highly precise post-processed kinematic GNSS solution of the UAV position. Top right: Google Earth (GE) view of UAV-borne L-band SAR backscatter intensity image with UAV flight trajectories in the foreground. Lower left: View of UAV-borne L-band differential interferometric phase ($-\pi$, π) and, on the lower right, coherence (0,1) for nominally zero spatial baseline and a temporal baseline of 3 minutes. The flight tube of these two repeat-tracks are within 1m radius. With the exception of forested areas in the near range and areas with severe foreshortening a very high coherence is obtained and the interferometric phase is also stable. Since no deformation took place within the 3 minutes time interval the stable phase arround zero is a good indicator for the performance of the interferometric system showing no significant residual phase errors and thus confirming the good performance of the system (see also [8]).

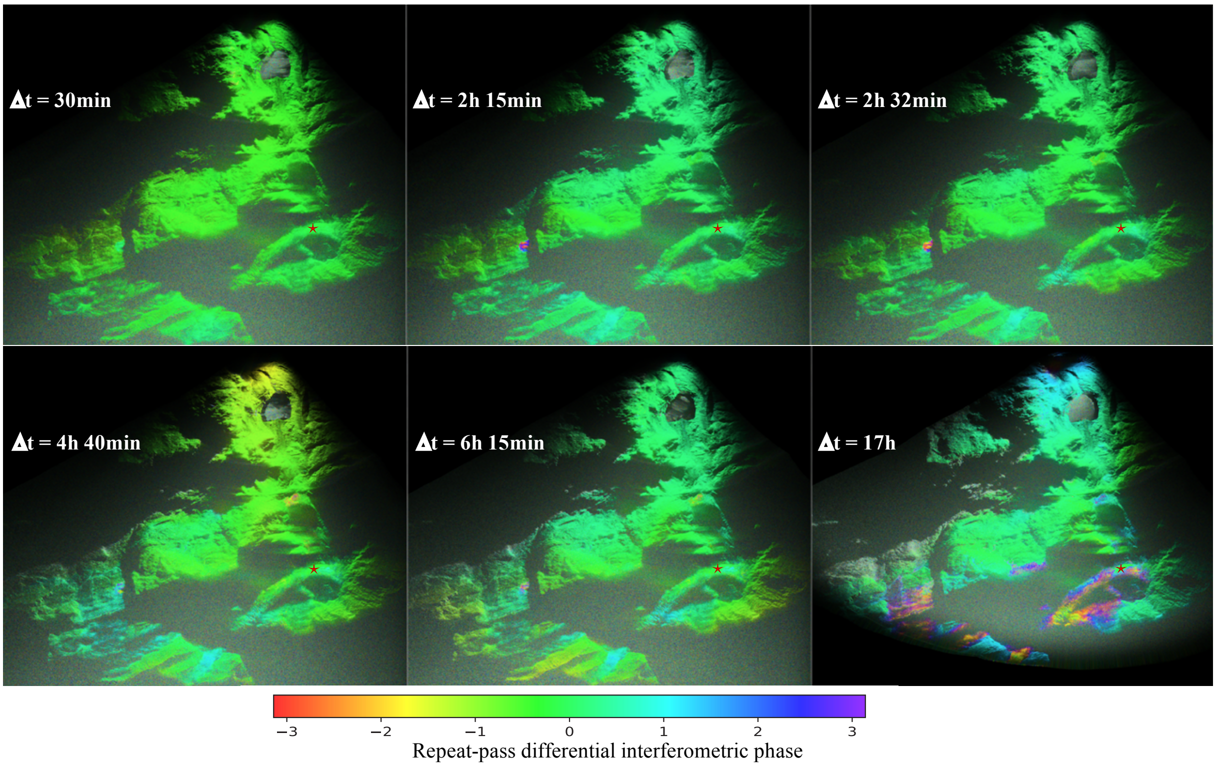

Figure 3. Differential interferograms of the Stein Glacier and the surrounding area in map coordinates (north = up) with temporal baselines of 30 min (upper left), 135 min (upper center), and 152 min (upper right), 280 min (lower left), 375 min (lower center), and 1020 min (=17h) (lower right). The 17h interferogram is obtained between two acquisitions with 1ms chirp duration; hence the limited range distance of ca. 4.68 km. All other interferograms shown are based on acquisitions a 2ms chirp duration. With a carrier frequency of 1.325 GHz (wavelength of 22.6 cm) an interferometric phase value of 2π translates to a line-of-sight displacement of the glacier of 11.3 cm (see also [8]).

REFERENCES

EFERENCES

[1] Frey, O., Werner, C. L., and Wegmuller, U.: "GPU-based parallelized time-domain back-projection processing for agile SAR platforms," in Proc. IEEE Int. Geosci. Remote Sens. Symp., July 2014, pp. 1132–1135. [Online]. Available: https://ieeexplore.ieee.org/document/6946629

[2] Frey, O., Magnard, C., Rüegg, M., and Meier, E.: "Focusing of airborne synthetic aperture radar data from highly nonlinear flight tracks," IEEE Trans. Geosci. Remote Sens., vol. 47, no. 6, pp. 1844–1858, June 2009. [Online]. Available: https://ieeexplore.ieee.org/document/4812049

[3] Frey, O., Meier, E., and Nüesch, D.: "Processing SAR data of rugged terrain by time-domain back-projection," in SPIE Vol. 5980: SAR Image Analysis, Modeling, and Techniques X, 2005.
DOI: https://doi.org/10.1117/12.627647

[4] Ribalta, A.: "Time-domain reconstruction algorithms for FMCW- SAR," IEEE Geoscience and Remote Sensing Letters, vol. 8, no. 3, pp. 396–400, May 2011.

[5] Stringham, C. and Long, D. G.: "GPU processing for UAS-based LFM-CW stripmap SAR," Photogrammetric Engineering & Remote Sensing, vol. 80, no. 12, pp. 1107–1115, 2014.

[6] Frey, O., Werner, C. L., Wegmuller, U., Wiesmann, A., Henke, D., and Magnard, C.: "A car-borne SAR and InSAR experiment," in Proc. IEEE Int. Geosci. Remote Sens. Symp., 2013, pp. 93–96 [Online]. Available: https://ieeexplore.ieee.org/document/6721100

[7] Frey, O., Werner, C. L., Hajnsek, I., and Coscione, R.: "A car-borne SAR system for interferometric measurements: development status and system enhancements," in Proc. IEEE Int. Geosci. Remote Sens. Symp., 2018, pp. 6508–6511. [Online]. Available: https://ieeexplore.ieee.org/document/8518840

[8] Frey, O., Werner, C. L., Coscione, R.: "Car-borne and UAV-borne mobile mapping of surface displacements with a compact repeat-pass interferometric SAR system at L-band," Proc. IEEE Int. Geosci. Remote Sens. Symp., July/Aug 2019, pp. 274-277.

18.2

"EMN Climate and Ocean Observation": A coordinated metrology network supporting ECVs and EOVs measurements

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Six so-called "European Metrology Networks" (EMNs) were set up in 2018 within the European Association of National Metrology Institutes (EURAMET) to promote the coordination between Metrology Institutes as well as with stakeholders for high priority societal and environmental themes. The aim of these EMNs is to analyse the European and global metrology needs and address these needs in a coordinated manner. We present here the "EMN for Climate and Ocean Observation" and its long-term goals.

Essential Climate Variables (ECVs) are physical, chemical, and biological variables that contribute to characterise Earth's climate. The Global Climate Observing System (GCOS) has defined a set of 54 ECVs up to present. In a similar way, the Global Ocean Observing System (GOOS) has defined 31 Essential Ocean Variables (EOVs) that, together with the GCOS oceanic ECVs, aim to provide a better understanding on ocean changes, human impacts and vulnerabilities, and to support the economic and social applications of the ocean system. The measurement of these ECVs entails challenging measurement accuracy to enable the global, multi-decadal observation of small climate trends. Metrological traceability and accuracy applied to measuring techniques of major importance for many ECVs and EOVs, such as remote sensing, will foster meeting those targets.

Remote sensing, particularly from satellites is the only means to achieve a truly global understanding of the planet, with more than 50% of the ECVs only observable from space. One challenge is understanding the transformation of the remote sensed digital count with the bio-geophysical variable of interest, requiring not only robust sensor calibration, but also analysis of retrieval algorithms, validation, with field deployable transfer standards. Although for some environmental monitoring activities, relative instantaneous maps can be adequate, for climate, reliably detecting a trend from a background of natural variability requires multiple decades and consequently satellites to achieve. This places severe challenges on the calibration accuracy of the sensors, their interoperability and the validation of bio-physical products and fundamentally the need for invariant community consensus references, ideally tied to the international system of units (SI), as maintained and disseminated by National Metrology Institutes.

The "EMN for Climate and Ocean Observation" will expand the metrology community's efforts - increasing support to the science, commercial and user community and seeking to build partnerships with remote sensing and in-situ practitioners to merge expertise towards a high quality climate observing system. In particular, METAS, the Swiss national metrology institute is active to support several ECVs, such as greenhouse gases, aerosols precursors and aerosols properties.

18.3
Downscaling NO_2 satellite observations to high-resolution air pollution maps

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Nitrogen oxides (NO_x = NO + NO_2) are precursors of ozone (O_3) and particulate matter (PM) that are crucial components of photochemical smog and wintertime air pollution. Concentrations of these air pollutants frequently exceed the legal limits in Switzerland, other European countries, and worldwide. To study the effect of NO_2 on public health, it is important to estimate an unbiased NO_2 exposure of the population, which requires maps of near-surface NO_2 concentrations with a resolution of 1 km or better (Bino et al. 2017).

In October 2017, the TROPospheric Monitoring Instrument (TROPOMI) was launched on-board the Sentinel-5 Precursor satellite. The instrument provides daily global NO_2 maps at a resolution of about 5 km. However, measurements represent a vertical column of NO_2 in the troposphere (Fig. 1 a, c) with a resolution lower than the required 1 km. In this project, we aim at attaining high-resolution maps of near-surface NO_2 concentrations from TROPOMI NO_2 observations by using different data-driven algorithms such as tree-based and neural network models. Besides NO_2 satellite observations, we used land use data (population density, road network, traffic volume, etc.), meteorological data (wind speed, temperature, precipitation, etc.) and geographic data (digital elevation map) for training the models with *in situ* NO_2 observations.

The models were applied to two distinct regions, northern Italy/Switzerland («Alpine region») and Belgium/Netherlands («Benelux region»), to include NO_2 pollution hotspots in Europe and to demonstrate the model performance under a wide range of topographic and meteorological conditions. Figure 1 shows observed and downscaled remotely sensed NO_2 for June and December 2018. Predictions compared well with the observations from ground-based air quality monitoring shown as time-series for two test sites (Fig. 1 e,f). Preliminary results seem consistent with seasonal changes and motivate future efforts of integrating publically available data, including satellite observations, for evaluating human exposure to atmospheric pollutants.

REFERENCES

Bino, M. et al., 2017: Improved Methodologies for NO_2 Exposure Assessment in the EU, Study accomplished under the authority of the European Commission, DG-Environment under service contract 070201/2015/SER/717473/C.3, Final report.

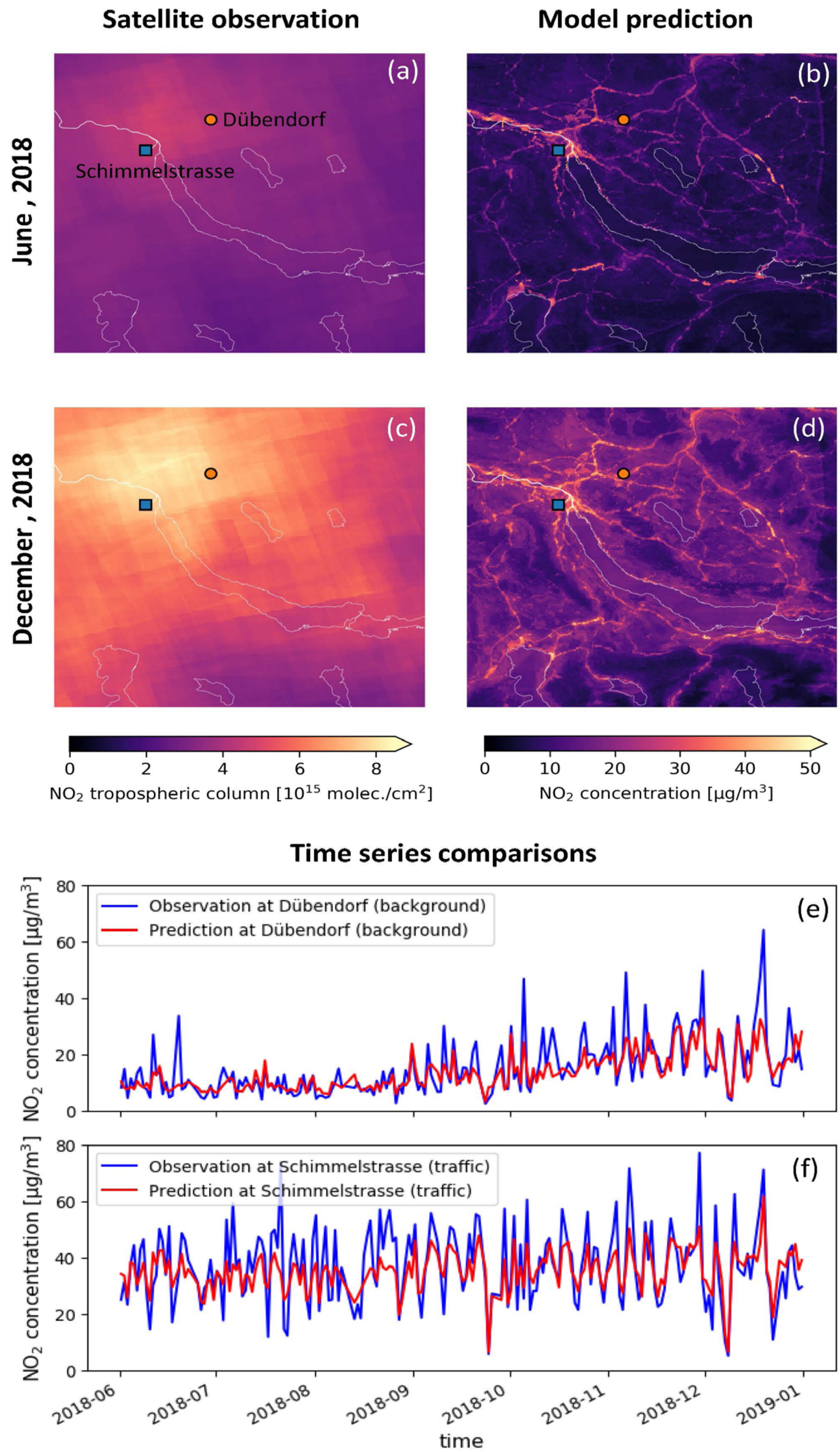

Figure 1: Vertical column density of NO_2 from TROPOMI around the city of Zürich as monthly averages for (a) June, and (c) December, 2018. By using a data-driven algorithm, the satellite observations were downscaled to a resolution of 100 m for both months (b and d, respectively). Predictions of NO_2 concentration time series were compared with observations at (e) Dübendorf (suburban, background, orange circle in a-d) and (f) Schimmelstrasse (urban, near traffic, blue squares in a-d).

18.4

Ultra-high resolution snow depth mapping using a UAV-based LiDAR scanner

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In forested watersheds with seasonal snowcover, knowledge of the spatial snow accumulation and melt patterns under the forest canopy is of key interest for hydrological applications. While optical sensors fail to obtain data below the trees, UAV-borne laser scanning is a very promising technology for snow depth mapping. In fact, laser altimetry opens new horizons for mapping terrestrial processes. However, Lidar scanning comes along with many challenges: for example, flight plans that allow for the extraction of the highest possible point density need to be developed. Moreover, the processing of the data is demanding and complex.

We use a state-of-the art Altigator Hydra 12 multicopter UAV and a Yellowscan Mapper II Lidar system for mapping the snow depth in a sub-alpine forest in south-eastern Graubünden, Switzerland. Snow-on and snow-off field campaigns took place in March and June 2019. The flights covered a 200*200 m area ranging from isolated larch trees to a closed mixed conifer stand. A flight plan with overlapping patterns yielded high point densities and horizontal and vertical accuracies close to 15 and 5 cm, respectively. For validation purposes, manual in-situ snow depth measurements were taken with a snow probe along pre-defined transects.

Combining two different approaches for extracting snow depth from the 3D point clouds, we propose a workflow to derive snow depth maps for forested areas. Subtraction of digital elevation models (DEMs) and the point to point comparison method are proposed, compared to the reference in situ HS data.
The derived UAV-based snow depth data will allow the investigation of spatial and temporal snow dynamics in terms of canopy structure at the spatial resolution of individual trees.

REFERENCES

Christian Ginzler and Martina L. Hobi(2015) Countrywide Stereo-Image Matching for Updating Digital Surface Models in the Framework of the Swiss National Forest Inventory, Remote Sensing, 7, 4343-4370, doi:10.3390/rs70404343
Giulia Mazzotti, William Ryan Currier, Jeffrey S. Deems, Justin M. Pflug, Jessica D. Lundquist and Tobias Jonas (2019) Revisiting Snow Cover Variability and Canopy Structure within Forest Stands: Insights from Airborne Lidar Data, Water Resources Research, doi:10.1029/2019WR024898

18.5

Machine learning assessment for tropospheric pathdelays prediction using meteorological parameters in Switzerland

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Atmospheric water vapor experiences high spatio-temporal variability which is reflected in the total tropospheric pathdelays of microwave satellite signals integrated along the zenith direction. This zenith total delays (ZTD) need to be estimated in space geodetic techniques such as GNSS. In this work we provide an alternative method to predict the ZTDs based on meteorological parameters. Indeed, the successful applicability of machine learning to several applications has raised our attention into investigating its potential use to compute the delays caused by the atmosphere into different space geodetic techniques. On the one hand, very accurate meteorological data are available from multiple online sources, advantageously providing many input data for training the network. On the other hand, we can directly use GNSS ZTDs (for example from the swisstopo network over Switzerland) as outputs for the training period. Therefore, GNSS pathdelays are generated without processing any GNSS data, but only using meteorological parameters.

In this work, we provide a preliminary assessment of this technique in which GNSS zenith pathdelays from the AGNES stations in Switzerland and meteorological parameters from the Swiss Meteorological Network (SwissMetNet) have been used for training and validation purposes for a period of 10 years. These stations are distributed all over Switzerland allowing the network to train and validate stations with different altitudes and meteorological conditions. Preliminary results show an accuracy of several mm up to 2 cm depending on the stations location.

18.6

Towards a global time series (1982 - 2018) of snow cover extent based on AVHRR GAC data – preliminary results of the ESA CCI+ Snow project

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Knowledge about the snow cover distribution is of high for climate studies, weather forecast, hydrological investigations, irrigation or tourism, respectively. The key aspects are the pronounced albedo change between snow cover and ground, but also water storage influencing run-off in the following spring and summer season. Distribution of snow on the globe is highly variable in space and time. Especially the annual variability of snow extent of the northern hemisphere ranges from 3 to 50 million km^2 from summer to winter. Furthermore, as snow cover is very sensitive to atmospheric temperatures, it is likely to show a significant response to a changing climate. Considering the high dynamic and the vast spatial distribution only satellite data can provide the needed information. For climate studies, a time series of more than 30 years is needed for statistically sound analyses as defined by WMO. Regarding these general conditions the only usable sensor is the Advanced Very High Resolution Radiometer (AVHRR) on the polar orbiting satellites NOAA-6 to -19 and Metop-A to -C providing data from 1982 until today (and most likely until 2025) with daily resolution.

Based on the products of the ESA Cloud cci project we have used the calibrated and geocoded AVHRR GAC (Global Area Coverage) data with a spatial resolution of 4 km including a consistent cloud map. The retrieval of snow extent considers the high reflectance of snow in the visible spectra and the low reflectance values in the near infrared expressed in the Normalized Difference Snow Index (NDSI). Additional thresholds related to topography and land cover are included to derive the fractional snow cover of every pixel.

In this presentation, we show preliminary results of the daily, global snow cover evolution spanning the complete time series of 37 years based on AVHRR GAC data and processed within the ESA CCI+ Snow project. Snow parameters, such as snow cover area percentage (SCA), snow cover duration (SCD), snow cover onset day (SCOD) and snow cover melting day (SCMD), are presented and interpreted. Furthermore, the benefits of this time series of almost 40 years fulfilling the requirements of WMO are highlighted by means of regional comparative assessments with higher resolved satellite data and in view of the climate modelling community.

18.7

Effects of spatial variability of NO_2 concentrations on NO_2 remote sensing at city scale studied with a 3D radiative transfer model

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Nitrogen dioxide (NO_2) is a relevant air pollutant with high spatial and temporal variability in cities, because of its strong localized sources combined with a short lifetime of a few hours. The spatial variability can be sampled with ground-based instruments and mapped with airborne or space-based imaging spectrometers. Different from ground-based in situ instruments measuring NO_2 at a single point in space, imaging spectrometers provide information on the total vertical column. For each measured spectrum, an NO_2 vertical column density (VCD) can be derived in two steps: First, a slant column density (SCD) representing the number of NO_2 molecules along the mean path of the photons from the sun to the instrument is fitted to the observed spectrum, and second, the SCD is converted to a VCD using an air mass factors (AMF). AMFs depend on Sun position, instrument viewing direction, surface reflectance and scattering of photons by gases and aerosols in the atmosphere and can be calculated from vertically resolved AMFs (layer-AMFs) with a radiative transfer model (RTM).
AMFs are traditionally computed under the assumption of a horizontally homogeneous atmosphere and land surface, which is not a proper assumption in cities where NO_2 concentrations and surface reflectance have a high spatial variability. To study the effects of horizontal inhomogeneity, we implemented three-dimensional (3D) box-AMFs in the MYSTIC solver of the libRadtran RTM (Emde et al. 2016, www.libradtran.org).

To demonstrate the importance of 3D box-AMFs in the trace gas retrieval, we simulated a NO_x plume emitted from a single stack with the GRAL dispersion model. The total NO_2 columns from the simulation are referred to as true VCDs in the following. We then converted the 3D NO_2 field to NO_2 SCDs using 3D box-AMFs for an imaging spectrometer on an aircraft flying parallel to the plume. From these synthetic SCDs, we calculated back the VCDs using 1D layer-AMFs for the same scenario. Finally, we compared these calculated VCDs to the true VCDs to highlight the errors introduced by using simplified 1D AMFs.

Figure 1a and 1b show the true VCDs obtained from a GRAL simulation and true SCDs calculated with the 3D box-AMFs. Figure 1c and 1d show the VCDs calculated with 1D box-AMFs and the differences between the calculated VCDs and true VCDs. The absolute differences are up to 26 μmol/m² (relative error of 32%) in the plume region. Effects are expected to be even higher for a plume further away from the ground (here the stack emits NO_x in the atmospheric layer between 100 and 200 m).

In conclusion, the new 3D box-AMFs implementation in MYSTIC allows us to study the effect of horizontal inhomogeneities of atmospheric and ground properties on the spatial distribution of box-AMFs and its influence on trace gas retrievals. In cities, where the NO_2 field is complex, not considering 3D box-AMFs can result in significant biases in the NO_2 retrievals.

REFERENCES

C. Emde, R. Buras-Schnell, A. Kylling, B. Mayer, J. Gasteiger, U.
Hamann, J. Kylling, B. Richter, C. Pause, T. Dowling, and L. Bugliaro (2016). The libRadtran software package for radiative transfer calculations (version 2.0.1). Geoscientific Model Development, (5), 1647-1672.

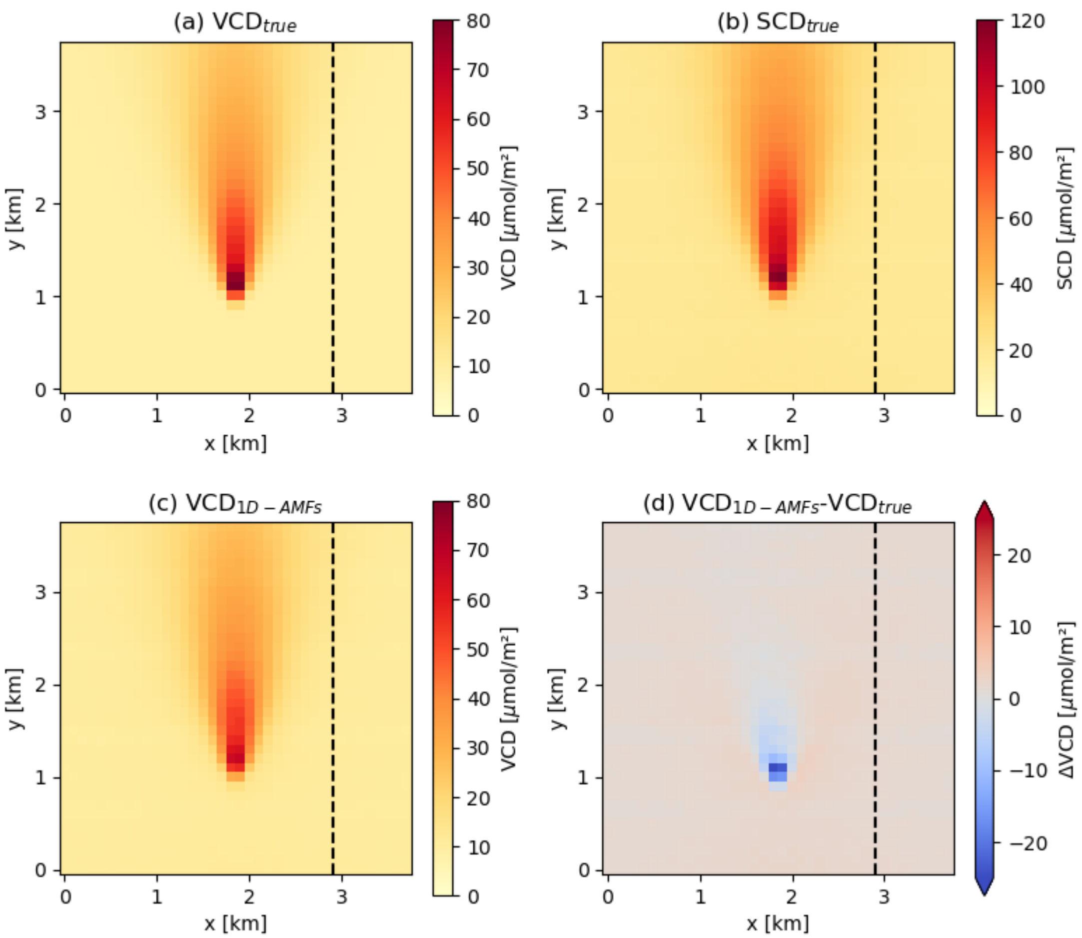

Figure 1. (a) Simulated (true) NO_2 VCDs (b) Synthetic SCDs computed from simulated VCDs combined with 3D box-AMFs for an airborne instrument flying parallel to the y-axis at x=2.9 km (dashed line) and at 6 km above surface. The sun is at a zenith angle of 40° and an azimuthal angle of 90° (west), (c) VCDs calculated from synthetic SCDs and 1D box-AMFs and (d) difference between calculated and true VCDs.

18.8

GlobDiversity: Remote Sensing-enabled Essential Biodiversity Variables to monitor key biodiversity characteristics at a global scale

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GlobDiversity is a European Space Agency (ESA) funded project involving a consortium of international research institutes. It is aimed at defining and developing Remote Sensing-enabled Essential Biodiversity Variables (RS-EBV); they comprise a collection of biophysical metrics, derived from satellite remote sensing (RS) datasets, which were shown to be relevant for global biodiversity monitoring. Three RS-EBVs were prioritized for development based on their suitability for biodiversity monitoring and include algorithms for retrieving Land Surface Phenology (LSP), Ecosystem Fragmentation and Canopy Chlorophyll Concentration. They were engineered using current best practices, high resolution Sentinel-2 and Landsat-8 time-series, and are currently being tested on ten pilot sites located across six terrestrial biomes. As a part of GlobDiversity, the University of Zurich (UZH) implemented LSP as a RS-EBV. LSP characterises recurrent biological events in the annual temporal profile of vegetated land surfaces at ecosystem scales, as observed by RS. Importantly, LSP has been widely used to measure the response of terrestrial ecosystems to changes in climate and environmental conditions, as well as a proxy for characterising species composition and ecosystem biodiversity. Currently, the algorithm testing and upscaling phases are taking place, with the objective of implementing the algorithms in an operational cloud computing system and processing them globally. Concurrently, their effectiveness at monitoring biodiversity and their usefulness for conservation applications is being demonstrated in four case studies undertaken by the consortium members. Here, UZH are investigating the biodiversity monitoring and conservation applications of RS-EBVs, particularly LSP, in Kytalyk National Park, Siberia. The focus is on demonstrating how RS-EBVs, together with ancillary datasets, can be used to evaluate the nesting habitat availability and breeding success of the Siberian White crane (*Grus leucogeranus*) and the lesser sand hill crane (*Grus canadensis*).

P 18.1

Water vapour trends in Switzerland based on data from ground-based microwave radiometry and GNSS ground stations

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Atmospheric water vapour plays a crucial role in the climate system. It is not only a strong greenhouse gas, but also affects many atmospheric processes such as the formation of clouds and precipitation. Water vapour is directly related to changes in temperature, as described by the Clausius Clapeyron relation. Analysing how water vapour changes in time is therefore important in a warming climate.

We asses changes of integrated water vapour (IWV) over Bern, Switzerland, by analysing data from a tropospheric water radiometer (TROWARA). We compared TROWARA data to reanalysis data from the Modern-Era Retrospective analysis for Research and Applications (MERRA2). Further, the data are compared to surrounding ground stations of the Global Navigation Satellite System (GNSS), which are part of the Automated GNSS Network for Switzerland (AGNES). We observe that the different datasets generally agree well, with differences within 10%.
We determined IWV trends of almost 25 years of data and found trends between 1 and 6% per decade. Trend differences depending on seasonal cycle are also presented, with slightly higher trends in spring and autumn. Further we found an altitude dependence of the trends, with larger trends for GNSS stations that lie at higher altitudes.

Our IWV trends are generally consistent with observed temperature changes. This confirms the positive temperature–water vapour feedback in a warming climate. However, we observe that not all data sets show trends that are significantly different from zero at 95% confidence interval. This insignificance of trends for some datasets emphasizes the need to continue to measure water vapour, with the aim to obtain stable long-term time series and to better understand water vapour feedbacks in a changing climate.

GNSS data is of high interest for this endeavour due to its measurement continuity and its good spatial coverage.

P 18.2

Rock slope deformation in the Grimsel Pass region, Switzerland

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The investigation of environmental parameters is crucial for the analysis and interpretation of several geo-hazards. In recent years, remote sensing approaches have been extensively applied on radar imagery to study slope instability. Differential Synthetic Aperture Radar Interferometry (DInSAR) is a powerful remote sensing technique capable to retrieve ground displacement in different scenarios. Space-borne DInSAR relies on the availability of images acquired from SAR sensor on board satellites orbiting 800 km above the Earth's surface. By analyzing the phase differences between two subsequent acquisitions over the same area it is possible to identify surface deformation relevant to slope instability with sub-centimetric accuracies.

In this work, we applied DInSAR on the recent ESA Sentinel-1 acquisitions to study slope processes in the Grimsel Pass region. The results show that slopes adjacent to Lake Grimsel and Lake Oberaar are affected by reversible surface displacements during summer periods. High resolution photogrammetric data and UAV-based high-resolution 3D slope models were also used to investigate slope morphology and rock mass fractures, to derive hypotheses on the potential causes of these processes, and to validate the remote sensing results.

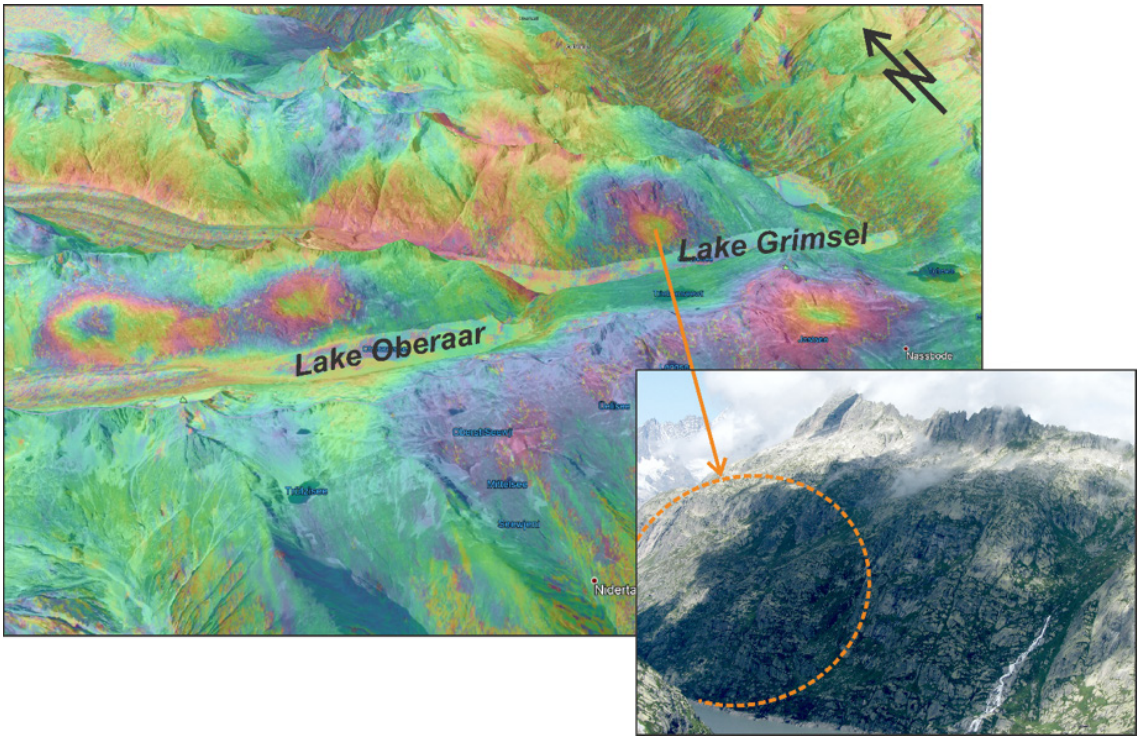

Figure 1. Surface deformation derived from DInSAR in the Grimsel Pass region (summer 2018) and photograph looking at the northern slope of Lake Grimsel.

P 18.3

Accuracy study of snow cover maps based on AVHRR data with different spatial resolution

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Snow is an essential natural resource and geophysical parameter that represents the largest part of the cryosphere. The significance of snow cover for the climate at a regional and global scale is already recognized. Thus, the proper monitoring of spatial and temporal variability of seasonal snow cover is crucial to understand changes in the climate system including hydrological processes, water management or snow-melt runoff.

The Advanced Very High Resolution Radiometer (AVHRR) provides the unique opportunity to retrieve long time series of more than 35 years to study earth surface process at a global scale on a daily basis. It is important to note that, Local Area Coverage (LAC) and Global Area Coverage (GAC) data from the AVHRR sensor was broadly used for snow cover mapping in the Alps individually. However, the main challenge is the availability of finer resolution LAC data (1.1 km) at a global scale. Therefore, we use reduced resolution GAC data (4.4 km) due to its global availability. To the best of our knowledge, the differences in snow maps occurring due to different resolution from both LAC and GAC data has not yet been investigated. In this study, we thus carry out an in-depth assessment of differences and similarities of winter snow cover products over different topography and land cover types based on AVHRR LAC and GAC data, aiming at estimating the accuracy of GAC snow cover maps for the European Alpine environment.

Here, we present preliminary results of the comparative assessment of LAC and GAC snow cover products. In particular, the influence of the topography and varying land cover types are investigated in order to be able to describe possible reasons for variations between the products. Pixel-wise fractional snow cover extent is obtained by applying the Normalized Difference Snow Index (NDSI) in combination with other band-related thresholds. A series of two winters is used to address the research aim in the regional context of the European Alps. This comparison of snow products based on LAC and GAC data shows their individual assets, points out discrepancies and highlight crucial information to be considered for the derivation of consistent fundamental climate data record.

P 18.4

Remote Sensing of Ecological Genetics

Schuman M.C., Czyz E., Li C., Shimizu K.K., Baldwin I.T., Schaepman M.

Recent, cutting-edge studies have demonstrated the ability of spectroscopic imaging and laser scanning techniques to identify plant species and quantify several biochemical and structural traits, and a few studies have differentiated plant genotypes. While catalogues of species and traits are now being established using multiple approaches, data on genetic diversity is more sporadic, and laborious to collect. Yet genetic diversity is a key determinant of adaptive potential for species in a changing climate. We aim to develop remote sensing approaches to describe plant genetic diversity and its distribution.

P 18.5

Perspectives for the monitoring of very slow landslides in Switzerland with InSAR

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Over Switzerland, hazards due to slope instabilities affect about 6% of the territory. It is therefore of outstanding importance to continuously monitor the rate of motion of landslides for the assessment of their hazard and the survey of their activity with time. Satellite Synthetic Aperture Radar (SAR) interferometry (inSAR) is one option for surface deformation monitoring over large areas, now entering an operational phase with the regular availability of Sentinel-1 data since 2014, see various nation-wide maps of land deformation recently released in Norway, Germany and the United Kingdom. Also in Switzerland there is a high interest on deformation maps and time series of surface motion from InSAR.

In our contribution we will discuss, based on results for the Loderio landslide in Canton Ticino, potential and limitations of current satellite SAR data with different carrier frequencies (L-, C- and X-band), ground resolutions (around 10, 20 and 2 meters), time intervals (46, 6, 34 and 11 days) and acquisition strategies (global versus on-demand, free versus commercial data) for the monitoring of very slow landslides (i.e. rates of motion of a few cm/year). Multi-temporal interferometric approaches using large data stacks are applied over this mountainous area, where sparse urbanization, large vegetated areas, snow-cover, layover/shadow, and atmospheric stratification and summer turbulences are introducing special processing challenges.

Figure 1. Photographs of the Loderio landslide.

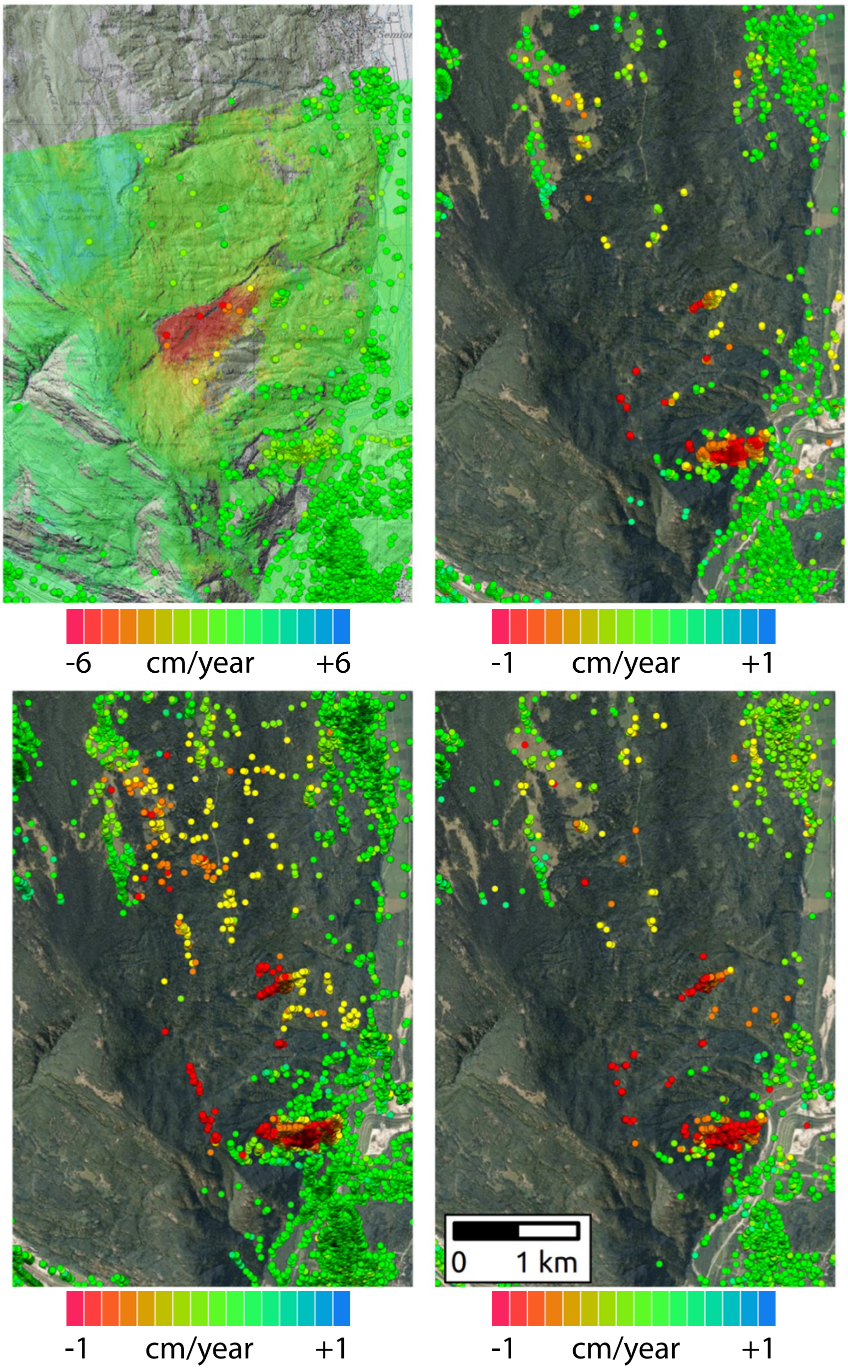

Figure 2. Multi-temporal SAR interferometry on the Loderio landslide using (from left to right, top to bottom) ALOS-2 PALSAR-2 from 2014 to 2018, Sentinel-1 from 2014 to 2018, TerraSAR-X from 2014 to 2017 and Radarsat-2 from 2011 to 2017.

P 18.6

Large-scale crop classification from satellite images

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Annual inspections of farmland in Switzerland is a time-consuming process and requires lots of human labor. Each year many farmlands are visited to validate the cultivated crop types reported by farmers and to inspect over-fertilization. These tasks are not only labor-intensive and time-consuming but also do not scale to the entire country in practice. Therefore, the Swiss Federal Office for Agriculture (BLW) has initiated a four-year project in 2018 to develop an automatic system for farmland inspection from satellite images. Within the scope of this project, we are currently working on crop type classification method from publicly available Sentinel-2 images.

Most previous work uses physics-inspired models. They compute one or multiple vegetation-related indexes, form time series, and feed them to a classifier, e.g, a random forest. Such models capture only a limited part of the complex reflectance distribution of the vegetation and its evolution. We posit that this is one of the factors that limit their performance, and undermines their robustness against noise in the data, even when advanced pre-processing techniques are used. Our approach is based on deep learning, which has recently shown great success in prediction tasks, from both image data and time series (e.g. in speech processing). We use a recurrent multi-layer neural network to learn the complex spectral, spatial and temporal patterns that differentiate different crop types from raw data. Our model is fed with a temporal sequence of images and encodes both spectral and temporal information, from which it then predicts the likelihoods of different crop types. We do not do any pre-processing, rather we let the model learn to disregard uninformative and noisy data, such as clouds and cloud shadows.

Here, we present the project aims, the processing methods, preliminary results, and initial validations.