Gamma Remote Sensing AG
ANNUAL REPORT 2022

RESEARCH AND DEVELOPMENT

ESA – CCI+ – Glaciers (2019-2022)

The main objectives of the CCI+ Glaciers Project (coordinated by University of Zürich, Switzerland) in the frame of the Climate Change Initiative (CCI) are to provide EO based services for glacier monitoring, as developed and demonstrated under the DUE GlobGlacier Project and CCI Glacier. GAMMA's responsibilities are in the glacier flow monitoring and in the service and system engineering. Furthermore, within Option 6 of the precursor project ESA CCI Glaciers, GAMMA is contributing to an Ice Marginal Lake Inventory of Greenland.

ESA – Glacier Science Alps (2021-2023)

The main objectives of the AlpGlacier project (coordinated by University of Zürich, Switzerland) are to provide enhanced observation capacity for glaciers in the Alps regarding surface flow velocity, snow cover, glacier lake size and slope movements around glaciers. GAMMA contributes to this project with its SAR competence.

ESA – CCI+ – Biomass (2018-2025)

The main objectives of the CCI+ Biomass Project (coordinated by Aberystwyth University, UK) in the frame of the Climate Change Initiative (CCI) are to provide EO based services for forest biomass monitoring. GAMMA has the technical lead, with responsibilities in the algorithm development, system engineering, system implementation and the generation of the global biomass products.

ESA – CCI+ – Permafrost (2018-2025)

The main objectives of the CCI+ Permafrost Project (coordinated by GAMMA, with T. Strozzi acting as project manager, and b.geos GmbH, with A. Bartsch acting as science leader) is to deliver a permafrost related climate data record which complies with the requirements of the climate user community. The work builds upon elements developed and demonstrated under the ESA DUE GlobPermafrost project. GAMMA's responsibilities are in the coordination of the work, mountain permafrost thematic products, overall system design engineering and the production of subsidence maps at Arctic permafrost sites.

ESA – CCI+ – Snow (2018-2025)

The main objectives of the CCI+ Snow Project (coordinated by ENVEO, Austria) in the frame of the Climate Change Initiative (CCI) is to provide essential climate variables for snow based on EO data. GAMMA's responsibilities are in the system design engineering and the system implementation of the AVHRR Snow Cover Fraction processor.

ESA –SMOS Expert Support Laboratory for Level 2 - Soil Moisture (2020-2024)

The tasks of the SMOS ESL for soil moisture include the development, implementation and assessment of SMOS soil moisture and additional land-surface retrieval algorithms. GAMMA contributed new algorithm ideas relevant for applications to the Cryosphere arising from 2-stream radiative transfer modeling that are now being further tested and that may be introduced at a later stage into the operational processor.

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ESA – Wide-Band Scatterometer Development (2017-2022)

In this project GAMMA developed and built the coherent, polarimetric 1 – 40 GHz scatterometer WBScat. A design incorporating a Vector Network Analyzer and a front end with 2 x 3 wide-band horn antennas was chosen. WBScat can be used in support of tower-based measurements of snow, crops and soil.

ESA – Scientific Campaign Data Analysis for an Alpine Snow Regime (SCANSAS, 2020-2022)

The aim of this activity is to perform an in-depth analysis of the ESA SnowLab and ESA SnowLabNG active and passive microwave data acquired within the two projects as well as the available meteorological data, snow physical data, and ground data. The resulting knowledge gain supports the definition of future microwave mission concepts dedicated to remote snow observations in terms of required data accuracy, optimal combination of frequencies, and observation geometry.

ESA Worldcover (2019-2023)

In an extension of the Worldcover Project the team under the lead of VITO develops in 2022/23 an updated global land cover map at 10 m resolution for 2021. GAMMA contributes the pre-processing of Sentinel-1 SAR data, including quality assessments and support to the thematic classification chains.

ESA Forest Carbon Monitoring (2021-2023)

The aim of this project under the lead of VTT is to develop a robust, reliable, and transparent approach for the monitoring of forest carbon. In the proposed approach optical and SAR EO data play a central role. In the context of the EU Green Deal an increasing demand for related services is expected. GAMMA contributes to the SAR data based elements.

ESA – BIOMAP (2022-2023)

The main objectives of the BIOMAP project, lead by GAMMA supported by Estellus, is the integration of active and passive microwave data towards a novel global record of woody aboveground biomass estimates.

Eurostars RAMON (2019-2022)

The objective of the Eurostars RAMON Project, coordinated by GAMMA with the partners SATIM and ICEYE Polska, are to design, develop and test an innovative radar-based landslide monitoring service to support different phases of the landslide risk management. The service combines existing, established elements as landslide velocity maps derived from stacks of satellite SAR data using Persistent Scatterer Interferometry with completely new near-real-time monitoring elements, as urgently required during crisis situations, made possible using a novel microsatellite constellation and terrestrial radars.

Re-processing of Global JERS SAR Data archive for JAXA (2022-2023)

In a JAXA-funded project, GAMMA Remote Sensing AG reprocesses the available SAR data archive of the Japanese Earth Resources Satellite (JERS-1, in operation 1992-1998). JAXA plans to make the data available.

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GAMMA SOFTWARE

In 2022 GAMMA continued to provide licenses for its user-friendly and high-quality software to support the entire processing from SAR raw data to products such as digital elevation models, deformation, and landuse maps. The software consists of the Modular SAR Processor (MSP), Interferometric SAR Processor (ISP), Differential Interferometry and Geocoding (DIFF&GEO), Land Application Tools (LAT), and Interferometric Point Target Analysis (IPTA), complemented by the stand-alone module for Geocoding and image registration (GEO). Furthermore, a time domain back projection processor (TDBP) is available to process SAR data acquired along curvilinear sensor trajectories such as GAMMA's car-borne L-band SAR measurements or airborne SAR data.

License sale activities were continued with new licenses sold in Europe, Asia, North America. User contacts indicate that the advanced algorithms and our competent support are important features of our software. This is also confirmed by an increasing number of running maintenance contracts. Many long-term users updated their license to the current version to be able to process data acquired by the newest SAR satellites (Sentinel-1, ALOS-2, PAZ, Gaofen-3, ICEYE, NOVASAR, ASNARO2, RCM, SAOCOM, Capella, StriX). The software also supports processing of data acquired with the GAMMA GPRI and L-band SAR instruments.

We also look forward to upcoming institutional and commercial SAR satellites. L-band SAR sensors (e.g. NISAR, ALOS-4, ROSE-L) will consistently become available in the near future. Frequent global coverage at C-band will be continued by Sentinel-1 with the satellites 1C and 1D. At X-band TerraSAR/PAZ and Cosmo Skymed 2nd Generation are available. And all this is complemented by an increasing number of commercial sensors and constellations.

Further information related to the GAMMA Software is available online:

> General information:
> www.gamma-rs.ch/software
> www.gamma-rs.ch/uploads/media/GAMMA_Software_information.pdf
> Technical reports, conference and journal papers:
> www.gamma-rs.ch/uploads/media/GAMMA_Software_references.pdf
> Release notes / upgrade information:
> www.gamma-rs.ch/uploads/media/GAMMA_Software_upgrade_information.pdf

GAMMA INSTRUMENT DEVELOPMENT

GAMMA WBScat / X- to Ku-band scatterometer (SNOWSCAT) / L-band Radiometer ELBARA

Under ESA contracts GAMMA developed the VNA based, polarimetric, 1-40 GHz Wide-Band Scatterometer (WBScat) and the X- to Ku-band scatterometer (SNOWSCAT) and the L-band Radiometer ELBARA. ESA provides now these instruments to scientists for their field measurements. There is one more ELBARA L-band radiometer on stock, ready to be sold.

GAMMA Portable Radar Interferometer (GPRI)

There was again a significant interest in the GAMMA Portable Radar Interferometer (GPRI). More than 30 instruments are in operation by users in Europe, North America and Asia. The primary application is displacement monitoring over glaciers, rock glaciers, rocks, slopes, and infrastructure. Besides the standard instruments, instruments supporting polarimetric and bistatic measurements were built. Our customers promote the instrument with their high-quality results.

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Further information and related technical reports, conference and journal papers are available online:
www.gamma-rs.ch/uploads/media/Instruments_Info/GAMMA_GPRI_information.pdf
www.gamma-rs.ch/uploads/media/Instruments_Info/GAMMA_GPRI_publications.pdf

GAMMA L-band SAR

The GAMMA L-band Synthetic Aperture Radar (SAR) has been successfully used for repeat-pass DInSAR-based mobile mapping of surface displacements with car-mounted and UAV-mounted system configurations, as well as a rail-mounted configuration. In 2019/2020, first GAMMA L-band SAR instruments were sold. The instrument also serves as a starting point for the development of airborne and high-altitude-platform (HAP) SAR instruments.

Further information and related technical reports, conference and journal papers are available online:
www.gamma-rs.ch/uploads/media/Instruments_Info/GAMMA_L-Band_SAR_information.pdf
www.gamma-rs.ch/uploads/media/Instruments_Info/GAMMA_L-Band_SAR_publications.pdf

EO SERVICES, CONSULTING AND TRAINING

Deformation Maps, DEMs , Landcover/Landuse and Change/Hazard Products

A variety of products were generated in 2022 for customers in Switzerland, Europe, and North America using data of the ERS, ENVISAT, Radarsat, ALOS-1/2, TerraSAR-X, Cosmo-Skymed, Sentinel-1, and ICEYE satellites. SAR, InSAR, offset tracking and Persistent Scatterer Interferometry (PSI) were used to generate forest biomass maps, deformation maps, deformation histories, terrain heights, and glacier velocity maps. For Sentinel-1 near-real-time processing capability is applied for glacier velocity and ground stability mapping. In 2022 we also continued providing services using the GAMMA Portable Radar Interferometer (GPRI) and the GAMMA L-band SAR.

Consulting

GAMMA's consulting activity included SAR and interferometric processing related aspects, application development support, and radar system engineering. GAMMA also supported users of GAMMA Instruments (GPRI, ELBARA, GAMMA L-band SAR, SnowScat, WBScat) with the acquisition and processing of the data. Furthermore, user specific adaptations of GAMMA microwave instruments were developed and implemented.

Training courses

In 2022 an online training course for SAR, SAR interferometry and an in-situ course on Interferometric Point Target Analysis (IPTA) took place. To support new software users we also provided documented demo examples and supported the users over the internet. Courses will again be scheduled for 2023 (IPTA training: 2-5. May 2023, InSAR training: 8. – 1.. May 2023, for further information see our homepage http://www.gamma-rs.ch). We also trained users in the operation of GAMMA Instruments (GPRI, GAMMA L-band SAR) and the related data processing.

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VARIA

In 2022 there were no variations to the GAMMA staff.

Our work was again affected by the COVID-19 pandemic. Travelling to customers, attending conferences, and holding training courses was still reduced. Project meetings were mainly on-line. Some of us are working partly from home.

GAMMA employees are members of national (SIP, SED, SGPF, CHGEOL, FAN) and international (IEEE, RSPSoc, AGU, EARSEL, EGU) organizations, acted as peer reviewers (various journals, books), were members of scientific committees, engaged in University teaching and PhD supervision (FSU Jena, ETH Zürich, SLU Umeå), and served on the "Board zur Qualitaetssicherung der Austrian Academy of Sciences" as reviewer in the process of an appointment.

PUBLICATIONS

Articles in journals and books:

Araza A. et al., "A comprehensive framework for assessing the accuracy and uncertainty of global above-ground biomass maps," Remote Sensing of Environment, vol. 272, Art. no. 112917, 2022. https://doi.org/10.1016/j.rse.2022.112917.

Bertone A. et al., "Incorporating InSAR kinematics into rock glacier inventories: insights from 11 regions worldwide," Cryosphere, vol. 16, Art. no. 7, 2022. https://doi.org/10.5194/tc-16-2769-2022.

Cartus O., M. Santoro, U. Wegmuller, N. Labriere, and J. Chave, "Sentinel-1 Coherence for Mapping Above-Ground Biomass in Semiarid Forest Areas," IEEE Geoscience and Remote Sensing Letters, v. 19, 2022. https://doi.org/10.1109/LGRS.2021.3071949.

Cicoira A. et al., "In situ observations of the Swiss periglacial environment using GNSS instruments," Earth System Science Data, vol. 14, Art. no. 11, 2022. https://doi.org/10.5194/essd-14-5061-2022.

Coscione R., I. Hajnsek, C. Werner, and O. Frey, "Assessing the impact of positioning errors in car-borne repeat-pass SAR interferometry with a controlled rail-based experiment," IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 15, pp. 8402–8415, 2022. https://doi.org/10.1109/jstars.2022.3193053.

Kellndorfer J. et al., "Global seasonal Sentinel-1 interferometric coherence and backscatter data set," Scientific Data, vol. 9, Art. no. 1, 2022. https://doi.org/10.1038/s41597-022-01189-6.

Kochtitzky W. et al., "The unquantified mass loss of Northern Hemisphere marine-terminating glaciers from 2000-2020," Nature Communications, vol. 13, Art. no. 1, 2022. https://doi.org/10.1038/s41467-022-33231-x.

Naderpour R., M. Schwank, D. Houtz, C. Werner, and C. Mätzler, "Wideband Backscattering From Alpine Snow Cover: A Full-Season Study," IEEE TGRS, vol. 60, pp. 1–15, 2022. https://doi.org/10.1109/TGRS.2021.3112772.

Naderpour R., M. Schwank, D. Houtz, and C. Matzler, "L-Band Radiometry of Alpine Seasonal Snow Cover: 4 Years at the Davos-Laret Remote Sensing Field Laboratory," IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 15, pp. 8199–8220, 2022. https://doi.org/10.1109/JSTARS.2022.3195614.

Paul F. et al., "Three different glacier surges at a spot: What satellites observe and what not," Cryosphere, vol. 16, Art. no. 6, 2022. https://doi.org/10.5194/tc-16-2505-2022.

Picard G., H. Läwe, and C. Mätzler, "Brief communication: A continuous formulation of microwave scattering from fresh snow to bubbly ice from first principles," Cryosphere, vol. 16, Art. no. 9, 2022. https://doi.org/10.5194/tc-16-3861-2022.

Rozendaal D. M. A. et al., "Aboveground forest biomass varies across continents, ecological zones and successional stages: Refined IPCC default values for tropical and subtropical forests," Environmental Research Letters, vol. 17, Art. no. 1, 2022. https://doi.org/10.1088/1748-9326/ac45b3.

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Sandells M. et al., "X-Ray Tomography-Based Microstructure Representation in the Snow Microwave Radiative Transfer Model," IEEE TGRS, vol. 60, pp. 1–15, 2022. https://doi.org/10.1109/TGRS.2021.3086412.

Santoro M., O. Cartus, and J. E. S. Fransson, "Dynamics of the Swedish forest carbon pool between 2010 and 2015 estimated from satellite L-band SAR observations," Remote Sensing of Environment, vol. 270, Art. no. 112846, 2022. https://doi.org/10.1016/j.rse.2021.112846.

Santoro M. et al., "Global estimation of above-ground biomass from spaceborne C-band scatterometer observations aided by LiDAR metrics of vegetation structure," Remote Sensing of Environment, vol. 279, Art. no. 113114, 2022. https://doi.org/10.1016/j.rse.2022.113114.

Stefko M., O. Frey, C. Werner, and I. Hajnsek, "Calibration and Operation of a Bistatic Real-Aperture Polarimetric-Interferometric Ku-Band Radar," IEEE Transactions on Geoscience and Remote Sensing, vol. 60, Art. no. 5106719, 2022. https://doi.org/10.1109/TGRS.2021.3121466.

Stefko M., S. Leinss, O. Frey, and I. Hajnsek, "Coherent backscatter enhancement in bistatic Ku-/X-band radar observations of dry snow," The Cryosphere, vol. 16, Art. no. 7, 2022. https://doi.org/10.5194/tc-16-2859-2022.

Strozzi T., A. Wiesmann, A. Kääb, T. Schellenberger, and F. Paul, "Ice Surface Velocity in the Eastern Arctic from Historical Satellite SAR Data," Earth System Science Data Discussions, vol. 2022, pp. 1–42, 2022. https://doi.org/10.5194/essd-2022-44.

Tao S. et al., "Increasing and widespread vulnerability of intact tropical rainforests to repeated droughts," Proceedings of the National Academy of Sciences of the United States of America, vol. 119(37), Art. no. e2116626119, 2022. https://doi.org/10.1073/pnas.2116626119.

Xu Y. et al., "Recent expansion of oil palm plantations into carbon-rich forests," Nature Sustainability, vol. 5, Art. no. 7, 2022. https://doi.org/10.1038/s41893-022-00872-1.

Yang H. et al., "Climatic and biotic factors influencing regional declines and recovery of tropical forest biomass from the 2015/16 El Niño," Proceedings of the National Academy of Sciences of the United States of America, vol. 119, Art. no. 26, 2022. https://doi.org/10.1073/pnas.2101388119.

Articles in conference proceedings:

Antropov O. et al., "Intercomparison of Earth Observation Data and Methods for Forest Mapping in the Context of Forest Carbon Monitoring," in Proc. IEEE Int. Geosci. Remote Sens. Symp., Jul. 2022, pp. 5777–5780. https://doi.org/10.1109/IGARSS46834.2022.9884618.

Frey O., C. Werner, A. Manconi, and R. Coscione, "High-resolution mobile mapping of slope stability with car- and UAV-borne InSAR systems," EGU General Assembly, 2022. https://doi.org/10.5194/egusphere-egu22-8587.

Frey O., C. Werner, and R. Caduff, "Dual-frequency car-borne DInSAR at L-band and Ku-band for mobile mapping of surface displacements," in Proc. of EUSAR 2022 - 14th European Conference on Synthetic Aperture Radar, Jul. 2022, pp. 489–492. https://ieeexplore.ieee.org/document/9944302.

Lavalle M., C. Telli, N. Pierdicca, U. Khati, O. Cartus, and J. Kellndorfer, "Global Sentinel-1 InSAR Coherence: Opportunities for Model-Based Estimation of Land Parameters," in Proc. IEEE Int. Geosci. Remote Sens. Symp., 2022, pp. 1133–1136. https://doi.org/10.1109/IGARSS46834.2022.9883082.

Stefko M., O. Frey, and I. Hajnsek, "Snow Characterization at Ku-Band with a Bistatic Polarimetric Ground-Based Radar," in Proc. IEEE Int. Geosci. Remote Sens. Symp., 2022, pp. 4256–4259. https://doi.org/10.1109/IGARSS46834.2022.9884442.

Strozzi T., R. Caduff, N. Jones, A. Manconi, and U. Wegmüller, "L-Band StripMap-ScanSAR Persistent Scatterer Interferometry in Alpine Environments with ALOS-2 PALSAR-2," in Proc. IEEE Int. Geosci. Remote Sens. Symp., 2022, pp. 1644–1647. https://doi.org/10.1109/IGARSS46834.2022.9884743.

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