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# Gamma Remote Sensing AG
# ANNUAL REPORT 2023

## RESEARCH AND DEVELOPMENT

### ESA – CCI+ – Glaciers (2018-2025)

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.

### ESA – Glacier Science in the Alps / AlpGlacier (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 for surface instability mapping in Alpine paraglacial environments using Sentinel-1 DInSAR techniques.

### 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. In 2023, GAMMA has produced a new set of maps from ENVISAT ASAR and Sentinel-1 C-band and ALOS-1 PALSAR-1 and ALOS-2 PALSAR-2 L-band SAR data depicting the global distribution of forest biomass at hectare scale resolution for the years 2010, 2017, 2018, 2019, and 2020.

### 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 – Wide-Band Scatterometer Development, CCN1 (2023-2024)**

In CCN1 of the ESA – Wide-Band Scatterometer Development addresses the use of the antenna gain measurements done at the ESA antenna range facility at ESTEC, and the focusing of WBSCAT measurements in the azimuth direction.

**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 land-surface retrieval algorithms. Initially it was all about the soil moisture algorithm. For several years now, the group has also been increasingly concerned with SMOS applications to the Cryosphere and to vegetation. 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. Further, we support the increasingly important topic of vegetation observation with fundamental research into microwave radiation transfer in vegetation.

**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. GAMMA is responsible for the development of physically-based modelling and retrieval approaches for ASCAT C-band scatterometer and SMOS and SMAP L-band radiometer data and the integration of active and passive radar derived biomass estimates to produce a new global record of forest biomass for the years 2016 to 2020.

**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.

## GAMMA SOFTWARE

In 2023 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.

In 2023 an ArcGIS plug-in was implemented to support ArcGIS Pro users with GAMMA functionality related to radar backscatter and coherence. A first version has been finalized and was sent out with the end-of-2023 release.

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, UMBRA, LuTan-1, Superview Neo-2). 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 2$^{nd}$ 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.

Further information and related technical reports, conference and journal papers are available online:
https://www.gamma-rs.ch/GPRI-specific-Publications
https://www.gamma-rs.ch/GPRI-application-Publications

### 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 2023 our development focus was on developing a lighter, more compact version of the L-band SAR to support operation from lighter drones. The instrument also serves as a starting point for the development of airborne and high-altitude-platform (HAP) SAR instruments and SAR instruments at different frequencies.

Further information and related technical reports, conference and journal papers are available online:
https://www.gamma-rs.ch/index.php/L-band-specific-Publications

## EO SERVICES, CONSULTING AND TRAINING

### Ground-motion mapping and monitoring in Switzerland using terrestrial and satellite radar

Ground-motion mapping and monitoring services were provided to private and public Swiss customers using terrestrial radar measurements acquired with GAMMA's Portable Radar Interferometer (GPRI) operated at Ku-band, using car-borne SAR measurements with GAMMA's L-band SAR, and using satellite SAR data (Sentinel-1, ALOS-2 PALSAR-2, TerraSAR-X, Radarsat).

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

A variety of products were generated in 2023 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 2023 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 2023, in-situ and online training courses for SAR, SAR interferometry and 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 2024 (InSAR training: 13-16. May 2024 at GAMMA, IPTA training: 22-25. Apr 2024 at GAMMA), 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.

## VARIA

In 2023, Tobias Batt started to work at GAMMA. With Tobias Batt we strengthen our in-house development and manufacturing of microwave instruments including design, production and repair of electronic circuit boards.

Travelling to customers, attending conferences, and holding training courses was recovering in 2023. Many project meetings were still held on-line, and some of us kept 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:**


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Xu F. et al., "Spatial Configuration Design for Multistatic Airborne SAR Based on Multiple Objective Particle Swarm Optimization," IEEE Transactions on Geoscience and Remote Sensing, pp. 1–17, 2023, doi: 10.1109/TGRS.2023.3326869.

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forest degradation," Nature Geoscience, vol. 16, no. 3, pp. 244–249, 2023, doi: 10.1038/s41561-023-01137-y.

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