SILVIA ULLO, GEMINE VIVONE, GÜLŞEN TAŞKIN, RONNY HÄNSCH, UJJWAL VERMA, DALTON LUNGA, AND CLAUDIO PERSELLO

Computer Vision for Earth Observation: The Third IEEE GRSS Image Analysis and Data Fusion School

Over the last decade, the importance of Earth observation (EO) data steadily increased. Today, it plays a pivotal role not only in scientific research but also in monitoring, analyzing, and modeling natural and anthropogenic processes in the atmosphere and on the surface of Earth, including its oceans, forests, ice and snow fields, and urban areas. It is also connected to the United Nations Sustainable Development Goals (SDGs), where 34 indicators across 29 targets and 11 goals can be informed with EO data, and more and more companies leverage EO data, e.g., for insurance in regions prone to natural disasters or smart farming.

GOALS OF THE IMAGE ANALYSIS AND DATA FUSION SCHOOL ON COMPUTER VISION FOR EARTH OBSERVATION

Nowadays, the quality and quantity of EO imagery calls for fully automatic methods that are able to efficiently and robustly analyze globally distributed samples. Computer vision (CV) methods—shown to be very successful in other areas, such as semantic or geometric interpretation of close-range imagery—promise to fulfill exactly this need by leveraging data-driven machine learning-based frameworks that model the complex relationship between spectral–spatial (and sometimes temporal) input and the target variable. The goal of the third IEEE Geoscience and Remote Sensing Society (GRSS) Image Analysis and Data Fusion (IADF) School on CV for EO (CV4EO) was to provide a general overview of the multitude of different aspects of how CV is used in EO applications together with deep insights into modern methods to automatically process and analyze remote sensing images (Figure 1).

Digital Object Identifier 10.1109/MGRS.2025.3558460
Date of current version: 11 August 2025

ORGANIZATION OF THE IMAGE ANALYSIS AND DATA FUSION SCHOOL ON COMPUTER VISION FOR EARTH OBSERVATION

ORGANIZING COMMITTEE

The school was organized by the IADF Technical Committee (TC) of the GRSS. The organizing committee consists of the following members:

1) Silvia Ullo, University of Sannio, Italy
2) Gemine Vivone, National Research Council, Italy
1) Gülşen Taşkın, Istanbul Technical University, Türkiye
2) Ronny Hänsch, German Aerospace Center, Germany
3) Ujjwal Verma, Manipal Institute of Technology, India
4) Dalton Lunga, Oak Ridge National Laboratory, United States
5) Claudio Persello, University of Twente, The Netherlands.

SPEAKERS

The third edition of the GRSS IADF school invited a diverse group of experts from different countries. This list included the following people (Figure 2):

- Prof. Persello, a professor at the University of Twente
- Dr. Fabio Pacifici, a senior scientist at Maxar Technologies, United States
- Prof. Michael Schmitt, a professor at the University of the Bundeswehr Munich, Germany
- Dr. Francescopaolo Sica, deputy head of the Chair of Earth Observation, University of the Bundeswehr Munich
- Prof. Mercedes Eugenia Paoletti, a professor at the University of Extremadura, Spain
- Zhaoyue Wu, a Ph.D. student at the University of Extremadura
- Prof. Pedram Ghamisi, head of the machine learning group at Helmholtz-Zentrum Dresden-Rossendorf, Germany, and a professor at Lancaster University, United Kingdom
- Weikang Yu, a Ph.D. student at Helmholtz-Zentrum Dresden-Rossendorf.

SPONSORS

We would like to thank our sponsors for supporting this initiative. In particular, special thanks goes to the GRSS for its primary support and to the University of Sannio for hosting the event. In addition, other sponsors contributed to this edition of the school. We list them in alphabetical order: Confindustria, Cosine, Cosmind, European Space Agency (ESA), Intelligentia, SMS Engineering, Strega Alberti, and Thales Alenia Space.

FIGURE 1. The GRSS IADF School on CV4EO logo.

PROGRAM

The IADF school was hosted by the University of Sannio, offering an extensive program that covered a wide range of topics, including IADF methods as well as artificial intelligence (AI) applications in EO and remote sensing.

Sixty-plus students from five continents—Africa, Asia, the Americas, Europe, and Oceania—and from Cameroon, India, Bulgaria, The Netherlands, Marocco, the United Kingdom, Italy, Nigeria, Romania, China, Australia, Iran, Norway, Egypt, Saudi Arabia, Ghana, Venezuela, Portugal, Germany, Pakistan, Spain, Armenia, Singapore, Türkiye, the United States, and Canada attended the school.

This three-day event covered technical topics and offered ample opportunities for the exchange of ideas, experiences, and real-world applications among lecturers and participants. At https://iadf-school.org/, it is possible to find the IADF school website, with all the information about the program and lecturers, including those of previous editions. The school provided participants with an inclusive and enriching educational experience, emphasizing collaborative learning, where they gained practical skills through interactive hands-on sessions in addition to theoretical classes. This strategy made sure that everyone in attendance had a stronger understanding of EO and its applications, which greatly improved their learning results.

The third edition of the IADF school took place from 11 to 13 September 2024. Before the official start, a half-day session was held in the afternoon, featuring short talks and discussions on GRSS and IADF

FIGURE 2. The 2024 IADF school speakers: (a) Prof. Persello, (b) Dr. Fabio Pacifici, (c) Dr. Francescopaolo Sica, (d) Zhaoyue Wu, (e) Prof. Mercedes Eugenia Paoletti, (f) Prof. Michael Schmitt, (g) Prof. Pedram Ghamisi, and (h) Weikang Yu.

technical activities, led by Dr. Pacifici, Prof. Vivone, and Rahisha Thottolil. The session also included a presentation on research at the ESA Φ-Lab by Dr. Alessandro Sebastianelli, along with an introduction to quantum computing for EO by Prof. Silvia Liberata Ullo. A brief online presentation on quantum computing challenges and opportunities was carried on by Classiq.

DAY 1: DEEP LEARNING FOR SUPERRESOLUTION AND SYNTHETIC APERTURE RADAR DATA ANALYSIS

The first day of the IADF school introduced the role of deep learning in remote sensing, focusing on superresolution techniques and synthetic aperture radar (SAR) data analysis. The morning session, led by Prof. Paoletti and Wu, included a lecture about traditional resampling methods, such as nearest-neighbor, bilinear, bicubic, and Lanczos upsampling, followed by deep learning approaches for superresolution. The session covered key deep learning architectures, including the superresolution convolutional neural network, very deep superresolution, and enhanced deep superresolution, and demonstrated their applications in improving satellite imagery resolution. The participants engaged in hands-on exercises in Python to implement superresolution techniques, reinforcing their understanding through practical experimentation. The afternoon session, presented by Prof. Schmitt and Dr. Sica, focused on deep learning applications in SAR image analysis. In the first part of the session, Prof. Schmitt covered deep learning models for SAR data analysis, focusing on how machine learning adapts to SAR's complex pixels, non-Gaussian noise, and unique radiometric and geometric properties. He discussed models for land cover classification, object detection, and geophysical parameter estimation. In the second part, Dr. Sica gave a lecture around a "from zero to hero" approach, introducing the fundamental principles of SAR imagery, Sentinel-1 missions, and various SAR acquisition modes. The session underscored the challenges associated with SAR image interpretation, such as geometric distortions and noise handling, and demonstrated practical implementations utilizing open source tools, such as the ESA's Sentinel Application Platform and Google Earth. After this session, a tour of Benevento, Italy, was organized, allowing participants to visit a United Nations Educational, Scientific, and Cultural Organization World Heritage Site.

DAY 2: MACHINE LEARNING AND EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT

Recognizing the critical role of sustainability in today's world, the second day of the school was devoted to how machine learning and EO contribute to addressing global environmental and societal challenges. Prof. Persello focused on the intersection of machine learning and EO for addressing the SDGs. He covered applications in mapping smallholder farms, monitoring urban deprivation, and delineating cadastral boundaries, highlighting the role of AI in providing scalable and cost-effective solutions for geospatial analysis. He also presented recent research efforts and results toward global-scale glacier mapping using deep learning, including uncertainty quantification in the model output. In the afternoon session, participants presented their work during a poster session, allowing for a more interactive and engaging exchange of ideas. The organizing committee and speakers reviewed the projects and selected the most notable ones. This session gave participants a chance to discuss their work in depth and receive feedback. In the evening, during a gala dinner, the winners were announced. More specifically, eight Best Poster Awards were presented to Milena Mincheva Atanasova, Michael Greza, Hamid Jafarzadeh, Francesco Mauro, Francesco Pasanisi, Thijs Van der Plas, Francesca Razzano, and Wenyu Yang. We thank our sponsors Cosine, the ESA, Intelligentia, and Thales Alenia Space for their support of these awards. Moreover, 10 travel grants from the GRSS were awarded to Kawai (Kristy) Chan, Jafarzadeh, Mobina Keymasi, Harish Khali, Manvel Khudinyan, Nelson Mattie, Negin Moghaddam, Ismail Olaniyi, Thottolil, and Luyao Zhang.

FIGURE 3. Moments from the 2024 IADF school: the (a) and (b) poster session, (c) gala dinner, and (d) city tour with students.

DAY 3: INSIGHTS, ETHICS, AND ARTIFICIAL INGELLIGENCE SECURITY IN REMOTE SENSING

On the last day of the IADF school, Prof. Pacifici gave a lecture entitled "From Pixels to Insights," covering the processing and analysis of satellite imagery for actionable insights.

He introduced the fundamentals of satellite imaging, including spectral and spatial resolution, geolocation accuracy, and analysis-ready data. The session explored radiometric and geometric corrections, highlighting calibration techniques, atmospheric compensation, and orthorectification. Concluding with real-world applications, he demonstrated how optimized satellite data support land use classification, vegetation mapping, and object detection in various industries. The afternoon session began with Prof. Ghamisi, who discussed responsible AI in EO, emphasizing fairness, transparency, and security in AI models. He covered bias mitigation, interpretability, and weakly supervised learning, demonstrating applications in land cover mapping and semantic segmentation. Yu concluded the school with a session on AI security and change detection in remote sensing. He explored adversarial attacks on AI models, methods for defense, and applications in disaster response and environmental monitoring. The session included hands-on demonstrations with state-of-the-art change detection models, marking the conclusion of the IADF school (Figure 3).

DISTRIBUTED MATERIAL

Through lectures, hands-on exercises, and demonstrations, participants gained a deep understanding of key topics in CV4EO, including machine learning in remote sensing, explainable AI for Earth science, big geodata, multisource image analysis, data fusion, SAR image analysis, and deep interpretable remote sensing. The related material is available at https://drive.google.com/drive/folders/1DexcR4xHJrp-Ldl20NEEl7Wjg4ijWrnu.

The lectures were recorded and made available online on the GRSS YouTube channel, including:

- *All welcome events*:
  - vice president of technical activities
  - vice chair of the GRSS IADF TC
  - ESA Φ-Lab introduction
  - quantum computing for EO
  - ESA Φ-Lab activities on quantum computing for EO
  - quantum computing with Classiq
  - overview of GRSS global activities
- *Lesson 1*: "Deep Learning in Superresolution"
- *Lesson 2*: "Deep Learning for SAR Data Analysis (Part 1)"
- *Lesson 2*: "Deep Learning for SAR Data Analysis (Part 2)"
- *Lesson 3*: "Machine Learning and Earth Observation for the Sustainable Development Goals"
- *Lesson 4*: "From Pixels to Insights"
- *Lesson 5*: "Responsible AI: A Few Examples in Remote Sensing (Part 1)"
- *Lesson 5*: "Responsible AI: A Few Examples in Remote Sensing (Part 2)."

IMAGE ANALYSIS AND DATA FUSION SCHOOL: FIND OUT ABOUT THE NEXT EDITION

After the successful third edition of the GRSS IADF school, a fourth one will be announced soon. It will follow the same theme as the 2024 edition, i.e., CV4EO. It will be an in-person event and will take place for the third time at the University of Sannio, between 16 and 19 September 2025. We look forward to seeing you in Benevento! Please stay tuned!

Join the GRSS IADF TC

You can contact the GRSS IADF TC chairs at iadf_chairs@grss-ieee.org. If you are interested in joining the IADF TC, please fill in the form on our website: https://www.grss-ieee.org/technical-committees/image-analysis-and-data-fusion. Members receive information regarding research and applications on IADF topics as well as updates on the annual Data Fusion Contest and all other activities of the IADF TC. Membership in the IADF TC is free! Also, you can join the LinkedIn IEEE GRSS Data Fusion Discussion Forum (https://www.linkedin.com/groups/3678437/) and X channel (@Grssladf).

CONCLUSION

The school program provided a diverse range of opportunities for developing knowledge in geoscience and remote sensing. It also fostered a sense of community among students, professionals, and researchers. Looking back, we are inspired by the collaborative spirit, exchange of ideas, and topics discussed. We would like to thank the GRSS and IADF TC for their support and all the lecturers who freely gave their time and expertise. A survey among the participants conducted after the school clearly showed that the event received significant attention and provided an exciting experience. All the comments have been collected and will be used to improve the format of the next editions.

AUTHOR INFORMATION

Silvia Ullo (ullo@unisannio.it) is with the Department of Engineering, University of Sannio, 82100 Benevento, Italy. She is a Senior Member of IEEE.

Gemine Vivone (gemine.vivone@imaa.cnr.it) is with the Institute of Methodologies for Environmental Analysis, National Research Council, 85050 Tito, Italy, and the National Biodiversity Future Center, 90133 Palermo, Italy. He is a Senior Member of IEEE.

Gülşen Taşkın (gulsen.taskin@itu.edu.tr) is with the Institute of Disaster Management, Istanbul Technical University, 34469 Istanbul, Türkiye. She is a Senior Member of IEEE.

Ronny Hänsch (ronny.haensch@dlr.de) is with the German Aerospace Center, 82234 Wessling, Germany. He is a Senior Member of IEEE.

Ujjwal Verma (ujjwal.verma@manipal.edu) is with the Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal 576104, India. He is a Senior Member of IEEE.

Dalton Lunga (lungadd@ornl.gov) is with Oak Ridge National Laboratory, Oak Ridge, TN 37830 USA. He is a Senior Member of IEEE.

Claudio Persello (c.persello@utwente.nl) is with the University of Twente, Twente, 7522, The Netherlands. He is a Senior Member of IEEE.