GABRIELE CAVALLARO, DORA BLANCO HERAS, AND MANIL MASKEY

High Performance and Disruptive Computing in Remote Sensing: The Third Edition of the School Organized by the HDCRS Working Group of the GRSS Earth Science Informatics Technical Committee

The University of Iceland in Reykjavik hosted the third edition of the "High Performance and Disruptive Computing in Remote Sensing" school from 29 May to 1 June 2023. This event was organized by the High-Performance and Disruptive Computing in Remote Sensing (HDCRS) Working Group of the IEEE Geoscience and Remote Sensing Society (GRSS) Earth Science Informatics Technical Committee (ESI TC). Its goal was to acquaint participants with advancements in parallel and scalable methods using state-of-the-art computing technologies as they apply to remote sensing (RS). In addition to fostering a deeper understanding of these topics, the school provided an opportunity for students and young professionals to network with established researchers in the field, thereby promoting collaboration in HDCRS interdisciplinary research.

The curriculum was comprised of 10 sessions organized into four major topics, blending theoretical discussions with hands-on tasks, and was facilitated by more than 20 lecturers. The event drew significant international interest, with more than 100 registrations from various countries. From these, the organizing committee selected 30 candidates for the in-person sessions in Reykjavik and allocated 10 travel grants (Figure 1). The selection process was thorough, considering factors, such as motivations, academic experience, and programming skills. Efforts were also made to ensure diversity and inclusion in the selection. To ensure broader access, all lectures were subsequently uploaded to the GRSS YouTube channel. The attendees, mainly Ph.D. students and postdoctoral researchers, came from four continents and 15 countries, as detailed in Figure 2.

Digital Object Identifier 10.1109/MGRS.2023.3347770
Date of current version: 1 March 2024

FIGURE 1. Participants and organizers.

OBJECTIVES OF THE SCHOOL

In the dynamic landscape of Earth observation (EO), the exponential growth in data from RS missions presents both an opportunity and a challenge. This surge in data, a result of advancements over the recent decades, has not only expanded our horizons in various EO applications but has also emphasized the need for advanced data processing and analysis techniques [1]. While RS sensors, both affordable and widely available, continue to gather invaluable data, the real task lies in harnessing this information effectively. Many emerging applications, rooted in these data, demand not just real-time processing but also scalable algorithms that require high computational power [2].

The answer to these demands lies in innovative computational approaches. From high-performance computing (HPC) platforms like clusters and grids to advanced accelerators—such as GPUs, edge-computing platforms, and even quantum computing (QC) solutions—the computational realm is vast and varied. Yet, the choice of a computational platform often depends on the nature of the problem and where it can be most effectively addressed, whether on supercomputers, standard in situ hardware, or onboard processing platforms for space [3], [4]. However, as we stand at this intersection of EO and advanced computing, challenges need to be met.

Two barriers significantly hinder the widespread use of HPC and advanced data analysis in RS. On the one hand, for many researchers, there is a lack of available computing infrastructure due to cost reasons; and on the other, the complexity of managing and programming the available infrastructures and using advanced data processing techniques is perceived as high. In many cases, HPC and advanced data processing techniques can be perceived as elements that increase development time. In contrast, our aim is to show that they are effective tools that can reduce execution time and, in many cases, provide access to data and techniques, such as deep learning algorithms that would otherwise be inaccessible, even when the task of validating vast amounts of data and drawing meaningful insights requires a depth of understanding. Raising knowledge about programming paradigms, computing platforms, and, more importantly, tools and libraries that facilitate the use of these platforms, are key elements for the advancement of RS research.

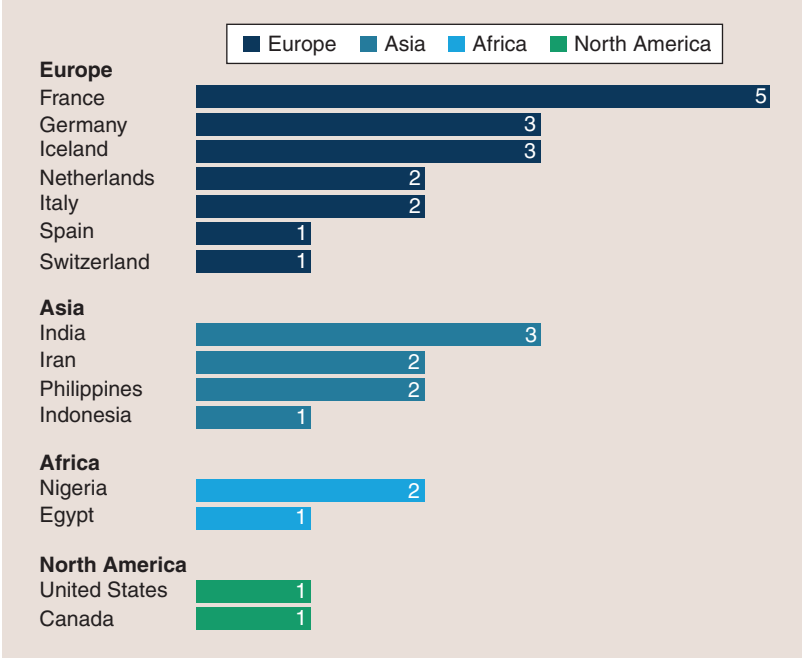


FIGURE 2. Geographical distribution of selected participants from the HDCRS School 2023 by country and continent.

Establishing HDRCS schools addresses the aforementioned challenges in the EO domain by offering structured learning to prepare the next generation of enthusiasts for RS and EO fields, focusing on the audience that may be more inclined to change their habits, namely young researchers. It aims to provide insights into using technologies like supercomputing, distributed computing, specialized hardware, edge computing, and QC in EO applications,

along with modern workflows and algorithms for large-scale data analysis. This event contributes to advancing the understanding and application of these technologies in the scientific community.

ORGANIZERS

This school was organized by the HDCRS Working Group of the GRSS ESI TC in cooperation with several partners. We acknowledge the GRSS, University of Iceland, European

Topics	Speakers	Affiliations
29 May		
Welcome at the University of Iceland and Opening of the School	Jón Atli Benediktsson	University of Iceland (Iceland)
Work and Activities of the HDCRS Working Group	Dora Blanco Heras	University of Santiago de Compostela (Spain)
	Gabriele Cavallaro	Forschungszentrum Jülich (Germany)/University of Iceland (Iceland)
Lowering the Barrier for Modern Cloud-Based Geospatial Big Data Analysis by Combined Use of Innovative and Traditional Infrastructure	Serkan Girgin	University of Twente (Netherlands)
Hyperspectral Technology: Inspiring Ideas, Challenges and Opportunities	José Francisco López	University of Las Palmas de Gran Canaria (Spain)
	Roberto Sarmiento	
An Overview of the European HPC Strategy and Highlights from the Icelandic HPC Communities	Hemanadhan Myneni	University of Iceland (Iceland)
30 May		
Data Science in Earth Observation and Remote Sensing: A Deep Dive into Large-Scale Harmonized Landsat Sentinel-2 Processing With AI Foundation Models	Manil Maskey, Sean Harkins, Brian Freitag, Muthukumaran Ramasubramanian, Iksha Gurung	NASA (USA)
	Linsong Chu, Paolo Fraccaro, Johannes Jakubik, Blair Edwards	IBM
31 May		
Scaling Remote Sensing and Earth Observation Data Analysis: Leveraging HTC/HPC Systems With the RSDAT Framework	Francesco Nattino	Netherlands eScience Center (Netherlands)
	Meiert Willem Grootes	
	Pranav Chandramouli	
1 June		
Introduction to Quantum Computing and its Ecosystem	Riccardo Mengoni	CINECA (Italy)
ESA Quantum Computing for Earth Observation (QC4EO): Current Activities and Perspectives	Bertrand Le Saux	ESA
Is Space Ready for the Quantum Leap? A Thales Alenia Space Perspective on Quantum Technologies for Earth Observation	Mattia Verducci	Thales Alenia Space Italia (Italy)
	Tommaso Catuogno	

FIGURE 3. The technical program of the HDCRS School 2023.

Space Agency (ESA), Thales Alenia Space, and EuroCC2 for sponsoring this event. We also extend our gratitude to all of the other partners for their support.

PROGRAM

RS yields a substantial amount of multisource data, which can be difficult to manage given its data and compute-intensive characteristics, particularly when using conventional computers and laptops. This RS data not only exemplify the V attributes associated with big data (such as volume, variety, veracity, and velocity) but also showcase high complexity and dimensionality [5]. This is evident from the complex interrelationships between natural and societal phenomena possessing notable correlations and multiple attributes. RS data demonstrate high complexity because of the association with intricate data models, necessitating rigorous processing, analysis, and modeling among these multifaceted systems. Given the sheer magnitude of raw RS data, it holds immense promise for both scientific exploration and commercial endeavors. Refining the underlying algorithms can potentially unearth novel insights and value. Hence, the HDCRS initiative focuses on prioritizing topics that leverage high-performance and innovative computing technologies for RS data analysis, aiming to address tangible EO applications at scale. The educational curriculum spanned over four days, encompassing a diverse range of lectures, as can be observed in Figure 3.

The first day of the school featured a program of five lectures. It began with two presentations: one introducing the University of Iceland and its involvement in RS and EO by its rector, and the other outlining the objectives and operations of HDCRS by its chairs. The third lecture introduced modern geospatial computing platforms and discussed how they can lower the barrier to modern cloud-based geospatial big data analysis by combining innovative and traditional infrastructure. The fourth lecture focused on hyperspectral imaging and showcased several applications, notably in RS through systems like unmanned aerial vehicles and satellites. The last lecture provided a discussion on Europe's HPC strategy, highlighting the international collaborations and contributions of the Icelandic HPC community across multiple scientific sectors. The day concluded with a social dinner and networking (Figure 4).

The second day centered around an intensive hands-on session that delved into the multifaceted realm of data science. Beyond mere data analysis, this session emphasized broader problems like data collection, storage, and ethics. The concept of foundation models was also introduced using the National Aeronautics and Space Administration Harmonized Landsat Sentinel-2 data. The participants were given the opportunity to fine-tune the model or detect flood and fire burn scars.

The third day offered another comprehensive hands-on session, focusing on large academic computing resources, such as high-throughput computing (HTC)/HPC systems. Notably, the Dask-based ecosystem was introduced, illustrating the use of the RS deployable analysis environment framework to upscale EO and RS data analysis using HTC/HPC systems and associated storage. This session encompassed tools for data access, retrieval, and storage, and showcased the escalation of processing and analysis workflows centered on EO datasets.

The final day emphasized QC for EO, consisting of three presentations. First was the introduction to QC and its capabilities surpassing those of traditional computers. This lecture navigated the complexities of QC, spotlighting potent algorithms suited for noisy intermediate-scale quantum devices and discussing the prevailing quantum hardware, software, and Europe's contributions to the sector. The subsequent lecture introduced the artificial intelligence-enhanced Quantum Initiative for Earth Observation by the European Space Agency, underlining the synergies between QC and EO. The objective was to recognize and exploit the intersection of QC and EO for upcoming prospects. The concluding lecture pivoted to the potential of applied quantum mechanics within the wider space industry.

SPEAKERS

The school hosted a diverse group of experts from academic institutions and industry (see Figure 5).

FIGURE 4. Social dinner 29 May 2023.

SLIDES AND RECORDING

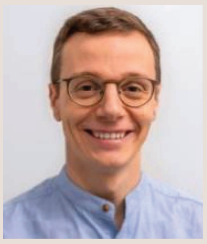
The lectures were recorded and made available online through the GRSS YouTube channel. Course material is available on the GRSS website [6].

JOIN THE ESI TC

To contact the ESI TC chairs, please e-mail esi_chairs@grss-ieee.org. If you're interested in joining the ESI TC, membership is free. You can complete the form available on our website: https://www.grss-ieee.org/technical-committees/earth-science-informatics/.

Jón Atli Benediktsson
(University of Iceland)

Dora Blanco Heras
(University of Santiago de Compostela)



Gabriele Cavallaro
(Forschungszentrum Jülich/University of Iceland)

Hemanadhan Myneni
(University of Iceland)

José Francisco López
(University of Las Palmas de Gran Canaria)

Roberto Sarmiento
(University of Las Palmas de Gran Canaria)

Serkan Girgin
(University of Twente)

Morris Riedel
(University of Iceland/ Forschungszentrum Jülich)

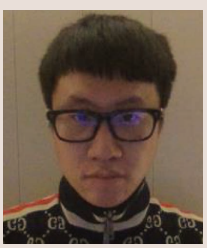
Manil Maskey
(NASA)

Sean Harkins
(NASA/Developmentseed)

Brian Freitag
(NASA)

Muthukumaran Ramasubramanian
(NASA/UAH)

Iksha Gurung
(NASA/UAH)

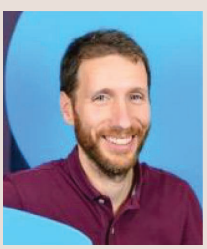


Linsong Chu
(IBM)

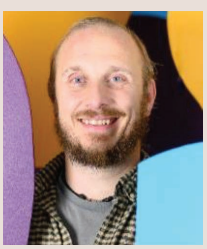
Paolo Fraccaro
(IBM)

Johannes Jakubik
(IBM)

Blair Edwards
(IBM)



Francesco Nattino
(Netherlands eScience Center)



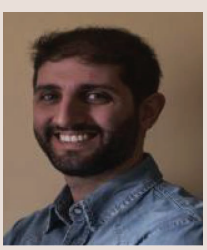
Meiert Willem Grootes
(Netherlands eScience Center)

Pranav Chandramouli
(Netherlands eScience Center)

Riccardo Mengoni
(CINECA)

Bertrand Le Saux
(ESA)

Mattia Verducci
(Thales Alenia Space)



Tommaso Catuogno
(Thales Alenia Space)

FIGURE 5. Speakers and supporters of the HDCRS School 2023.

CONCLUSION

HDCRS members were delighted to receive overwhelmingly positive feedback for the school. This encouragement strengthens our commitment, and we are looking forward to organizing the fourth edition. We plan to address new topics, seeking to promote the adoption of new technologies and tools related to efficient data processing. In addition to the core academic program, we are also planning a series of social activities to foster camaraderie and networking among participants. Registrations for the upcoming edition will commence in spring 2024. Furthermore, to provide diverse experiences and cater to a global audience, we are contemplating relocating future editions of the school to various other locations.

AUTHOR INFORMATION

Gabriele Cavallaro (g.cavallaro@fz-juelich.de) is with the Forschungszentrum Jülich, 52428 Jülich, Germany, and with the University of Iceland, 107 Reykjavik, Iceland. He is a Senior Member of IEEE.

Dora Blanco Heras (dora.blanco@usc.es) is with the Centro Singular de Investigación en Tecnoloxías Intelixentes, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain. She is a Senior Member of IEEE.

Manil Maskey (manil.maskey@nasa.gov) is with the National Aeronautics Space Administration, Huntsville, AL 35805 USA. He is a Senior Member of IEEE.

REFERENCES

[1] D. Tuia et al., "Artificial intelligence to advance Earth observation: A perspective," 2023, *arXiv:2305.08413*.

[2] G. Cavallaro et al., "High-performance and disruptive computing in remote sensing: HDCRS—A new working group of the GRSS earth science informatics technical committee," *IEEE Geosci. Remote Sens. Mag.*, vol. 10, no. 2, pp. 329–345, Jun. 2022, doi: 10.1109/MGRS.2022.3145478.

[3] N. Wedi et al., "Destination earth: High-performance computing for weather and climate," *Comput. Sci. Eng.*, vol. 24, no. 6, pp. 29–37, Nov./Dec. 2022, doi: 10.1109/MCSE.2023.3260519.

[4] G. Giuffrida et al., "The Φ-Sat-1 Mission: The first on-board deep neural network demonstrator for satellite earth observation," *IEEE Trans. Geosci. Remote Sens.*, vol. 60, pp. 1–14, 2022, doi: 10.1109/TGRS.2021.3125567.

[5] H.-D. Guo, L. Zhang, and L.-W. Zhu, "Earth observation big data for climate change research," *Adv. Climate Change Res.*, vol. 6, no. 2, pp. 108–117, Jun. 2015, doi: 10.1016/j.accre.2015.09.007.

[6] "HDCRS summer school 2023," GRSS-IEEE, Piscataway, NJ, USA, 2023. [Online]. Available: https://www.grss-ieee.org/community/groups-initiatives/high-performance-and-disruptive-computing-in-remote-sensing-hdcrs/hdcrs-summer-school-2023/

GRS

TECHNICAL COMMITTEES *(continued from p. 198)*

their time and expertise. A survey among the participants conducted after the school clearly showed that the event received high attention and provided an exciting experience. All of the comments have been collected and will be used to improve the format of the next editions.

AUTHOR INFORMATION

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

Gemine Vivone (gemine.vivone@imaa.cnr.it) is with the National Research Council-Institute of Methodologies for Environmental Analysis, 85050 Tito Scalo, 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, Turkey. 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 Bengaluru, Manipal Academy of Higher Education, 576104 Udupi, India. He is a Senior Member of IEEE.

REFERENCES

[1] "2023 IEEE GRSS IADF school." IADF. Accesssed: Dec. 2023. [Online]. Available: https://iadf-school.org/

[2] R. Roscher. "Explainable machine learning." Sciebo. Accesssed: Dec. 2023. [Online]. Available: https://uni-bonn.sciebo.de/s/YA0zxAhu4LlBiOU

[3] F. Tupin and E. Dalsasso. "SAR processing repository." Télécom Paris. Accesssed: Dec. 2023. [Online]. Available: https://gitlab.telecom-paris.fr/ring/iadf-2023-sar-processing

[4] M. Mommert. "Efficient learning repository." GitHub. Accesssed: Dec. 2023. [Online]. Available: https://github.com/mommermi/iadfschool2023_efficientlearning

[5] P. Gamba. "Fusion of heterogeneous sensors for change detection in urban area." Google Drive. Accesssed: Dec. 2023. [Online]. Available: https://drive.google.com/file/d/1cjBrVN3FFos6gTmNaT9fav3Ej33hueL1/view?usp=sharing

[6] "2023 IEEE GRSS IADF school." ILN. Accesssed: Dec. 2023. [Online]. Available: https://iln.ieee.org/public/contentdetails.aspx?id=11ECA9BDA72640B89EFF4B28D970F4EC

[7] "LinkedIn IEEE GRSS data fusion discussion forum." LinkedIn. Accesssed: Dec. 2023. [Online]. Available: https://www.linkedin.com/groups/3678437/

GRS