ALBERTO MOREIRA, JASMEET JUDGE, FRANCESCA BOVOLO, AND ANTONIO PLAZA
IEEE GRSS Awards Committees Chairs

IGARSS 2021Virtual Symposium: Impressions of the First Days

Hopes were high that we would be able to attend the 41st Annual IEEE International Geoscience and Remote Sensing Symposium (IGARSS) in the beautiful city of Brussels, Belgium, in person. Unfortunately, due to the pandemic, it was not feasible to arrange such a big event in a physical venue. The organizers therefore invited the geoscience and remote sensing community (Figure 1) into a virtual environment, which included presentations, 3D rooms in an exhibition hall, the possibility to chat with colleagues and exchange ideas, and even a job fair to search and share offers.

The theme of the conference, held 11–16 July 2021, was "Crossing Borders," and it was an apt one since organizing the event was a joint effort of the Low Countries: The Netherlands and Belgium, which share a strong background in science and technology, including geoscience and Earth observation. The organizing team did everything in its power to make IGARSS 2021 a great virtual symposium. The program included more than 1,500 oral and 1,000-plus multimedia presentations. Well before the opening and plenary session on 12 July, videos of the presenting authors' and plenary speakers' talks were recorded to ensure professional and trouble-free sessions. Participants have access to the presentations and sessions on the symposium website until the end of the year.

WELCOME ADDRESSES AT THE OPENING SESSION

The opening ceremony was held Monday, with remarks from Ramon Hanssen, (joint general chair), Joost Vandenabeele (joint general chair), and Michal Shimoni (technical program cochair) explaining the conference concept (Figure 2). For Belgium and The Netherlands, engineering has had historic importance: to be habitable and prosperous, the Low Countries have had to adjust to changing natural circumstances through the help of engineering. Geoscience and remote sensing are increasingly important because they deliver key inputs for responsible policy decisions. The three chairs explained how the meaning of "Crossing Borders," which they chose in 2017, well before the pandemic, changed through time and how they had to adapt to the international COVID-19 situation. They found ideas for the structure of the technical program that led to a "recalibration" of the conference itself and made the program broader and richer. With an enthusiastic local organizing team, they even started a high-school education initiative with more than 500 pupils from 20 Belgian schools and a well-received summer school program.

After the introduction, David Kunkee, 2021 IEEE Geoscience and Remote Sensing Society (GRSS) president, gave a welcome address (Figure 3) and discussed the Society's activities. The GRSS is a global community with 4,800 members in 70 Chapters and 23 Student Chapters, and it has 11 ambassadors in regions where a Chapter may form in the future. The Society organizes courses and lecture series, has webinars and online educational content, provides members with opportunities for networking and personal development, sponsors symposia and conferences, supports community developed tools, and disseminates premium science. Its mission is providing technology for the benefit of humanity.

KEYNOTE SPEECHES AT THE PLENARY SESSION

After the welcome address, the plenary session began with presentations by three distinguished speakers (Figure 4), as summarized in the following:

1) "TROPOMI Methane Observations: Guiding a New Era in Methane Observations From Space in Support of Emission Reductions," by Prof. Ilse Aben, senior scientist at Space Research Organization Netherlands and the coprincipal investigator and coinitiator of the Tropospheric Monitoring Instrument (TROPOMI).

Digital Object Identifier 10.1109/MGRS.2021.3101275
Date of current version: 28 September 2021

2) "Aerospace Robotics for Environmental Monitoring," by Dr. Sreeja Nag, senior research scientist and principal investigator at the Bay Area Environmental Research Institute/NASA Ames Research Center and head of autonomy systems validation at Nuro.
3) "European Innovation and Space Initiatives Making a Difference at a Global Scale," by Patrick Child, deputy director general and director general of research and innovation at the European Commission.

(a)

(b)

(c)

FIGURE 1. The IGARSS 2021 Symposium. The website was adapted to the virtual format of the symposium. In a prerecorded video, (a) Prof. Ramon Hanssen (joint general chair), (b) Michal Shimoni (technical program cochair), and (c) Joost Vandenabeele (joint general chair) invite participants to the conference.

Prof. Aben opened her lecture (Figure 5) by introducing TROPOMI, a single instrument on the *Sentinel-5 Precursor* satellite, developed by The Netherlands and the European Space Agency and operational since May 2018. It is part of the European Union (EU) Copernicus Program and the first atmospheric Sentinel mission. Prof. Aben explained how the project measures the atmospheric concentration of many molecules (O_3, NO_2, SO_2, HCHO, CO, CH_4) and the Absorbing Aerosol Index. TROPOMI is a passive grating imaging spectrometer using a "push broom" concept. It measures a strip of 2,600 km in nadir viewing from east to west in less than 1 s. It consists of 200 individual observations with a spatial sampling of 7×5.5 km^2. The satellite makes almost 15 orbits a day, which means it basically covers the whole Earth in 24 h, combining daily global coverage with high spatial resolution.

Methane is an important anthropogenic greenhouse gas and a good target for short-term mitigation. Satellites can help to find large methane emission sources, which is not an easy task because the lifetime of methane in the atmosphere is 10 years, meaning that measurements at a certain location include background methane coming from elsewhere. Measurement validation is performed, with the help of a network of Total Carbon Column Observing Network stations in more than 20 locations around the globe, by determining the average difference between satellite and ground station measurements.

Prof. Aben discussed some of the project's successes. In Queensland, Australia, it observed surface and underground coal mines acting as major emitters, with methane discharges that were substantially larger than reported to the UNFCCC. Working with the Canadian company GHGSat, it was also able to detect anomalies in a gas pipeline in Turkmenistan. The program provides artificial intelligence-powered automatic detection of methane plumes and emission quantification not only from the oil and gas industry but from coal mines, landfills, Russian compressor stations, and unlit flares in West Turkmenistan. It combined TROPOMI with other high-spatial-resolution instruments to detect and pinpoint super emitters globally. This

FIGURE 2. (From left) Hanssen, Shimoni, and Vandenabeele deliver opening remarks.

information is important for helping authorities to act, and for this, TROPOMI can be seen as a real game changer.

The second speaker, Dr. Nag, drew parallels between robotics applications and challenges related to self-driving cars and satellites (Figure 6). A robot in a self-driving car needs to be able to answer basic localization questions (where am I?) with respect to known map features, perception (who else is around, and what are they doing?), prediction (what will they do next?), planning (what do I do next?) and control (do it!). Every spacecraft has some level of robotics, and satellites need to answer the same questions.

The extent of vehicle autonomy is defined by how much we can minimize humans in the loop. The self-driving car industry has established five levels of autonomy, from none at all to full automation, and the concept also applies to Martian rovers (e.g., Curiosity), rockets (e.g., the Geosynchronous Satellite Launch Vehicle), human-carrying spacecraft (e.g., SpaceX Dragon), and instruments (e.g., the Hubble telescope). Space vehicles are level 3 autonomous because they do not always have time to make critical decisions with human involvement; satellites, for example, have ground station contact only every 4–6 h. Dr. Nag and her colleagues focus their research on reaching level 4 autonomy for satellites and instruments that monitor Earth and help Earth science.

Automation in space beyond level 3 is very resource constrained, which is problematic for five key parameters: communication, power, pointing, propulsion, and operation. It is very difficult to increase these parameters without adding mass and driving launch costs higher. Resolving this could lead to higher-level applications and better robotics, which, in time, would enable us to mine and manufacture in space, using resources from the Moon, asteroids, and other planets. Better robotics would also improve inspection and servicing, making it easier to fix faulty satellites and instruments in space. There are additional challenges for satellites, such as dynamic connectivity and tradeoffs between resolution and coverage. Many applications need different instruments at varying spatiotemporality, and there is always competition for computing power and resources.

FIGURE 3. GRSS President Dr. David Kunkee welcomes attendees.

FIGURE 5. Prof. Aben delivers her plenary session speech "TROPOMI Methane Observations: Guiding a New Era in Methane Observations From Space in Support of Emission Reductions."

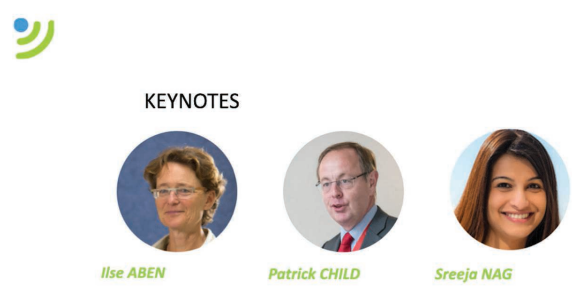


FIGURE 4. The plenary session keynote speakers: Prof. Ilse Aben, Patrick Child, and Dr. Sreeja Nag.

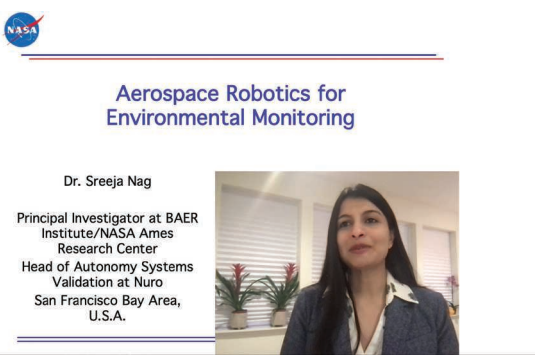


FIGURE 6. Dr. Nag makes her presentation, "Aerospace Robotics for Environmental Monitoring."

There are approximately 1,800 active satellites in space, but future megaconstellations could hike the number to more than 20,000. Having a large number of satellites leads to heavy traffic, which could increase the number of accidents, creating space debris (there are more than 20,000 tracked debris objects larger than 10 cm). Space traffic management (STM) is a challenge because current procedures cannot scale with the exponential growth of satellite companies and spacecraft. To automate interactions among the players in the STM ecosystem, Dr. Nag and her colleagues built a prototype network using a service-based architecture. Any participant can use it modularly and contribute to it, which enhances innovation in the field of autonomy for avoiding collisions and cleaning up space junk.

In the final section of her talk, Dr. Nag listed a few examples of problems she and her colleagues are working on to reach level 4 autonomy for making observational decisions in environmental monitoring. She discussed the role NASA plays in funding and furthering space ventures in areas that the market cannot support, but she also considers start-ups and spin-offs important. One can learn a lot from their insights and use their technologies for environmental monitoring and Earth science.

Child, the third speaker, said research and innovation supported by the EU play a vital role in tackling the planetary challenges we are facing, especially climate change. Obtaining reliable and rapid scientific observations helps us to respond effectively to climate change and improve our preparedness. European funding programs, in particular, Horizon Europe, the EU space program and Digital Europe, are designed to support this. Investments in research and innovation accelerate green and digital transitions to support the European Green Deal.

EU countries plan to invest in research and innovation under national recovery and resilience plans after COVID 19. Horizon Europe is the EU's new funding program and has a budget of 95 billion euros for 2021–2027. The first requests for proposals were published in June 2021. Promoters want to launch five EU missions to achieve ambitious and directly relevant goals, for example, missions for healthy oceans and climate-neutral smart cities, and partnerships between public and private sectors to pool resources to tackle challenges.

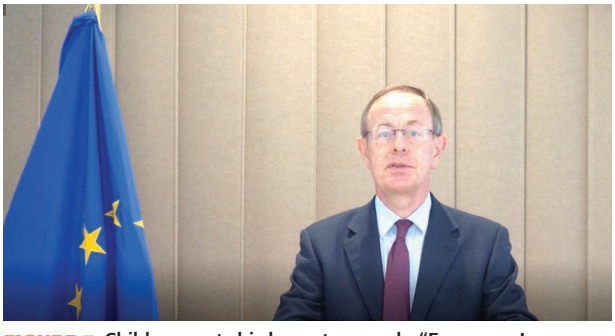


FIGURE 7. Child presents his keynote speech, "European Innovation and Space Initiatives Making a Difference at a Global Scale."

Child highlighted European initiatives and success stories in space and digital fields (Figure 7). Europe is a global leader in the analysis of daily and seasonal variations of population exposures to hazards and risks. A key component of the EU space program is Copernicus, a global program for Earth observation that has a full open data policy. Digital solutions are increasingly critical to understanding climate risks and resilience, and innovations are producing benefits for citizens. The Global Human Settlement Layer applies artificial intelligence to big Earth observation data. The *Atlas of the Human Planet* for 2020 outlines more than 30 examples of applications and is also a key deliverable of the Human Planet Initiative conducted by the Group on Earth Observation (GEO). The GEO is a partnership of more than 100 national governments and 100-plus organizations. It aims for coordinated, comprehensive, and sustained Earth observation, and it is building a global Earth observation system that will use data to improve people's lives and help governments make evidence-based decisions.

Research innovation and space action are indispensable when it comes to tackling global challenges. Investments in these fields through programs such as Horizon Europe and the EU space program are therefore fundamental not only for Europe but for the rest of the world. The GEO shows the benefit of working together, and this is vital because global challenges need global solutions.

MAJOR AWARDS CEREMONY

Following the plenary speeches, Prof. Alberto Moreira, GRSS major awards chair, opened the awards ceremony. As in the past, the opening and plenary session was chosen as the venue to recognize GRSS members elevated to the grade of IEEE Fellow and the recipients of the Society's four major awards.

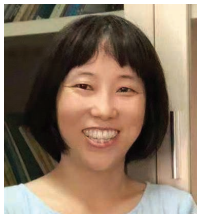
IEEE FELLOW AWARDS

The grade of IEEE Fellow recognizes unusual distinction in a profession and is conferred by invitation of the IEEE Board of Directors to a person of outstanding and extraordinary qualifications and experience in designated fields. The IEEE bylaws limit the number of members who can be advanced to Fellow in any year to one per mil of the membership, exclusive of students and affiliates. To qualify, a candidate must be a Senior Member and be nominated by an individual familiar with his or her achievements. Endorsements are required from at least five IEEE Fellows and the IEEE Society best qualified to judge. For GRSS members, the Society's Fellow Committee completes the first nominee evaluations. After that, the IEEE Fellow committee, consisting of some 50 IEEE Fellows, carefully evaluates the nominations, considering Society rankings, and presents a list of recommended candidates to the Board of Directors.

On average, the GRSS performs better than other Societies with respect to the number of elected Fellows every year. The following GRSS members were elevated to Fellow, effective 1 January 2021:

- Prof. Jun Li, Sun Yat-sen University, Guangzhou, China
- Dr. Zhao-Liang Li, Institute of Agricultural Resources and Regional Planning, French National Center for Scientific Research, Illkirch, France
- Prof. Xiuping Jia, School of Engineering and Information Technology, University of New South Wales, Canberra, Australia
- Dr. Jeffrey R. Piepmeier, Instrument Systems and Technology Division, NASA Goddard Space Flight Center, Greenbelt, Maryland, United States
- Prof. Xiao Xiang Zhu, Department of Earth Observation Data Science, Remote Sensing Technology Institute, German Aerospace Center, Germany
- Prof. Lizhe Wang, School of Computer Science, China University of Geosciences, Wuhan.

JUN LI



Prof. Jun Li received her Fellow Award with the citation "for contributions in hyperspectral image processing." She is a full professor at Sun Yat-sen University, where she founded her own research group on hyperspectral calibration and learning in 2013. Since then, she has obtained several funding grants at the national and international level. She has published more than 160 journal papers, has been a GRSS Distinguished Lecturer since 2018, and chairs the GRSS Guangzhou Chapter. In January 2021, she began a term as editor-in-chief of *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.*

ZHAO-LIANG LI

Dr. Zhao-Liang Li received his Fellow Award with the citation "for contributions to thermal infrared remote sensing." He received his Ph.D. degree in terrestrial environmental physics from the University of Strasbourg, France, in 1990. Since 2013, he has been with the Institute of Agricultural Resources and Regional Planning, French National Center for Scientific Research. He has authored or coauthored more than 200 refereed journal articles, contributed to 14 book chapters, and coauthored five monographs. He has served as an associate editor of *IEEE Transactions on Geoscience and Remote Sensing* since 2015.

XIUPING JIA

Prof. Xiuping Jia received her Fellow Award with the citation "for contributions to feature mining and classification of hyperspectral images." She has been with the School of Engineering and Information Technology, University of New South Wales, since 1988, and she is currently an associate professor. She has authored or coauthored more than 160 journal papers addressing various topics, including data correction, feature reduction, and image classification using machine learning techniques. She serves as associate editor-in-chief of *IEEE Transactions on Geoscience and Remote Sensing.*

JEFFREY R. PIEPMEIER

Dr. Jeffrey R. Piepmeier received his Fellow Award with the citation "for contributions to microwave radiometry to improve calibration, radio frequency interference filtering, and polarimetry." He is chief engineer for passive microwave instruments in the Instrument Systems and Technology Division, NASA Goddard Space Flight Center. He is deputy study coordinator for NASA aerosols, clouds, convection, and precipitation decadal survey architecture study and has contributed to various leadership roles on the cubesat projects IceCube, CubeSat Radiometer Radio Frequency Interference Technology Validation and SigNals Of Opportunity P-band Investigation. He has received several awards, including NASA's Exceptional Engineering Achievement Medal.

XIAO XIANG ZHU

Prof. Xiao Xiang Zhu received her Fellow Award with the citation "for contributions to artificial intelligence and data science in Earth observation and global urban mapping." She is a professor of data science in Earth observation at the Technical University of Munich, and she heads the Department of Earth Observation Data Science, Remote Sensing Technology Institute, German Aerospace Center. Since 2019, she has led the Helmholtz Artificial Intelligence Cooperation Unit, and since 2020, she has been the director of the International AI Future Lab: Artificial Intelligence for Earth Observation. She also serves on the scientific advisory boards of several research organizations.

LIZHE WANG

Prof. Lizhe Wang received his Fellow Award with the citation "for contributions to high performance computing in processing, analysis and applications of remote sensing imagery." He is the dean of the School of Computer Science, China University of Geosciences. His research interests include remote sensing data processing and digital Earth and geological information. He is a fellow of the Institute of Engineering Technology and the British Computer Society, and he is an associate editor of *IEEE Journal on Miniaturization for Air and Space Systems*. He received a National Science Foundation of China Distinguished Young Scholars award, a National Leading Talents of Science and Technology Innovation award, and a 100 Talents Program of the Chinese Academy of Sciences award.

GRSS MAJOR AWARDS

The call for nominations for the GRSS Education Award, GRSS Outstanding Service Award, GRSS Industrial Leader Award, and GRSS Distinguished Achievement Award are posted on the Society's website and announced in its newsletter. Nomination forms are available at http://www.GRSS-ieee.org/about/awards/. Any member, with the exception of Administrative Committee (AdCom) members, can nominate deserving individuals. Typically, there are three to five candidates each year. An independent Major Awards Evaluation Committee makes final selections, which are approved by the GRSS president and AdCom. The following major awards were presented:

- GRSS Education Award
- GRSS Outstanding Service Award
- GRSS Industry Leader Award
- GRSS Distinguished Achievement Award.

FIGURE 8. Prof. Adriano Camps, recipient of the 2021 GRSS Education Award.

FIGURE 9. Prof. Paolo Gamba, recipient of the 2021 GRSS Outstanding Service Award.

GRSS EDUCATION AWARD

The Education Award was established to recognize individuals who make significant educational contributions to the field. Winners are selected considering the significance of their contributions in terms of innovation and overall impacts. Their work can be at any level, including K–12, undergraduate and graduate teaching, professional development, and public outreach. It can also be in any form (e.g., textbooks, curriculum development, and educational program initiatives). GRSS membership or affiliation is required. Awardees receive a certificate and plaque.

The 2021 GRSS Education Award was presented to Prof. Adriano Camps (Figure 8), Electromagnetics and Photonics Engineering Group, Department of Signal Theory and Communications, Polytechnic University of Catalonia, Spain, with the citation "in recognition of significant educational contributions to Geoscience and Remote Sensing." He has been a full professor since 2007. His research interests include microwave remote sensing, remote sensing using signals of opportunity, nanosatellites, and radio-frequency interference detection/mitigation techniques. He has published more than 233 journals papers and eight book chapters, and he coauthored a book on satellite remote sensing. He has advised 27 Ph.D. students and more than 140 master's students. He is the scientific coordinator of the university's CommSensLab and principal investigator of the university's first four nanosatellite missions. He served as the IGARSS 2020 general cochair.

GRSS OUTSTANDING SERVICE AWARD

The Outstanding Service Award was established to recognize individuals who have performed outstanding service for the benefit and advancement of the Society. It is considered annually but not presented unless a suitable candidate is identified. The following factors are suggested for consideration: leadership innovation, activity, service, duration, and breadth of participation and cooperation. GRSS membership is required. Awardees receive a certificate and plaque.

The 2021 GRSS Outstanding Service Award was presented to Prof. Paolo Gamba (Figure 9), University of Pavia, Italy, with the citation "in recognition of outstanding service for the benefit and advancement of the Geoscience and Remote Sensing Society." He is a professor, and he leads the Telecommunications and Remote Sensing Laboratory. He served as editor-in-chief of *IEEE Geoscience and Remote Sensing Letters* from 2009 to 2013 and as chair of the GRSS Data Fusion Committee from 2005 to 2009. He has been an AdCom member since 2014, served as GRSS president from 2019 to 2020, and is currently the GRSS junior past president. He served as IGARSS technical cochair in 2010, 2015, and 2020. During his term as president, he has strongly promoted an open community of communities in the GRSS.

GRSS INDUSTRY LEADER AWARD

The GRSS established the Industry Leader Award to recognize individuals who have made significant contributions during a sustained period of time in industrial and commercial remote sensing. The evaluation committee may give preference to an individual who 1) is a GRSS member; 2) has made notable additions to remote sensing system engineering, science, and technology; 3) has advanced the dissemination and commercialization of remote sensing products; and 4) has demonstrated leadership in promoting remote sensing science and technology. The selection criteria include the significance, quality, and impact of candidates' activities, contributions, and achievements. The award is considered annually and presented if a distinguished candidate is identified.

The 2021 GRSS Industry Leader Award was presented to Rafal Modrzewski (Figure 10), chief executive officer and cofounder of ICEYE, Finland, with the citation "in recognition of leadership in the creation of a commercial satellite constellation delivering high resolution synthetic aperture radar observations and leading the corporate infrastructure to distribute this data." ICEYE operates a constellation of small radar imaging satellites, providing access to timely and reliable Earth observation data. It was the first company to miniaturize a synthetic aperture radar (SAR) satellite, making it possible to launch more units to reliably image any location on Earth, every few hours, every day. With its growing SAR satellite constellation, ICEYE offers its partners a set of unprecedented imaging capabilities, accessing any area of interest faster, more frequently, and at a lower cost. Modrzewski has received several recognitions, including a place on the 2018 Forbes 30 Under 30 Europe list.

GRSS DISTINGUISHED ACHIEVEMENT AWARD

The Distinguished Achievement Award was established to recognize individuals who make significant technical contributions within the scope of the GRSS, usually through a sustained period. In selecting the winners, factors including the quality, significance, and impact of nominees' contributions; contribution quantity; activity duration; papers published in archival journals; papers presented at conferences and symposia; patents; and advancement of the profession are considered. IEEE membership is preferable but not required. The award is considered annually and presented only if a suitable candidate is identified. Awardees receive a plaque and certificate.

The 2021 GRSS Distinguished Achievement Award was presented to Prof. Kun-Shan Chen (Figure 11), Guilin University of Technology, China, with the citation "in recognition of contributions to microwave scattering and emission modelling of rough surface, and radar image simulation and understanding." He is a distinguished professor, and his research interests include microwave remote sensing and intelligent signal processing and data analytics for radar. He has authored or coauthored more than 180 journal papers and contributed to more than 10 books and book chapters. He was an AdCom member (2010–2014), a founding chair of the GRSS Taipei Chapter, and the founding deputy editor-in-chief of *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*. He also served as IGARSS Technical Program Committee cochair in 2016, 2017, and 2020, and he was a member of the *Proceedings of the IEEE* editorial board (2014–2019). He is currently a member of the *IEEE Access* editorial board and an associate editor of *IEEE Transactions on Geoscience and Remote Sensing*.

SYMPOSIUM INTRODUCTION AND TECHNICAL PROGRAM

The technical program included the following scientific themes:

- "Between Countries and Research Institutes"
- "Between Types of Platforms (from Satellites to Drones)"
- "Between Data Sources"
- "Between Disciplines."

FIGURE 10. Rafal Modrzewski, recipient of the 2021 GRSS Industry Leader Award.

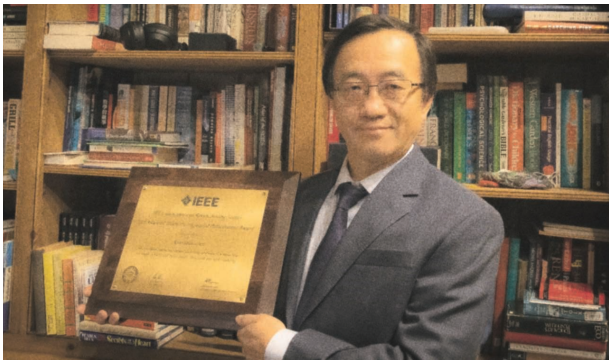


FIGURE 11. Prof. Kun-Shan Chen, recipient of the 2021 GRSS Distinguished Achievement Award.

Table 1 provides paper submission and registration statistics. The highest number of papers was submitted from Europe (46%), followed by Asia (31%), the United States and Canada (18%), South America (3%), Africa (2%), and Oceania (1%). The technical program was organized in 248 oral sessions with 1,130 papers, and 104 multimedia sessions with 904 papers. Because the conference was virtual, each session required a session manager. A total of 702 session chairs and 115 session managers supported the event and ensured that the proceedings flowed smoothly via Zoom. The hard work of the IGARSS organizers (Figure 12) and volunteers made the symposium a great success.

FUTURE IGARSS SYMPOSIA

The AdCom met in July 2021 and confirmed future IGARSS conferences, as follows:

- IGARSS 2022: Kuala Lumpur, Malaysia, 17–22 July
- IGARSS 2023: Pasadena, California, United States, 16–21 July
- IGARSS 2024: Athens, Greece, 7–12 July.

The final selection process for the IGARSS 2025 venue is underway, and a decision should be announced shortly. You are invited to participate in future IGARSS symposia, and we look forward to meeting you at IGARSS 2022 (www.igarss2022.org).

TABLE 1. PAPER SUBMISSION AND REGISTRATION DETAILS FOR IGARSS 2021.

PRESENTATIONS AND ATTENDANCE						
TOTAL PAPERS SUBMITTED	TOTAL PAPERS ACCEPTED	WITHDRAWN	SESSIONS	TOTAL REGISTERED	STUDENTS	COUNTRIES
2,555	2,335	94	352	2,947	771	72

ACKNOWLEDGMENT

The authors would like to thank Klara Antesberger for her great support in the compilation and Sandra Middeler for reviewing this article.

GRS

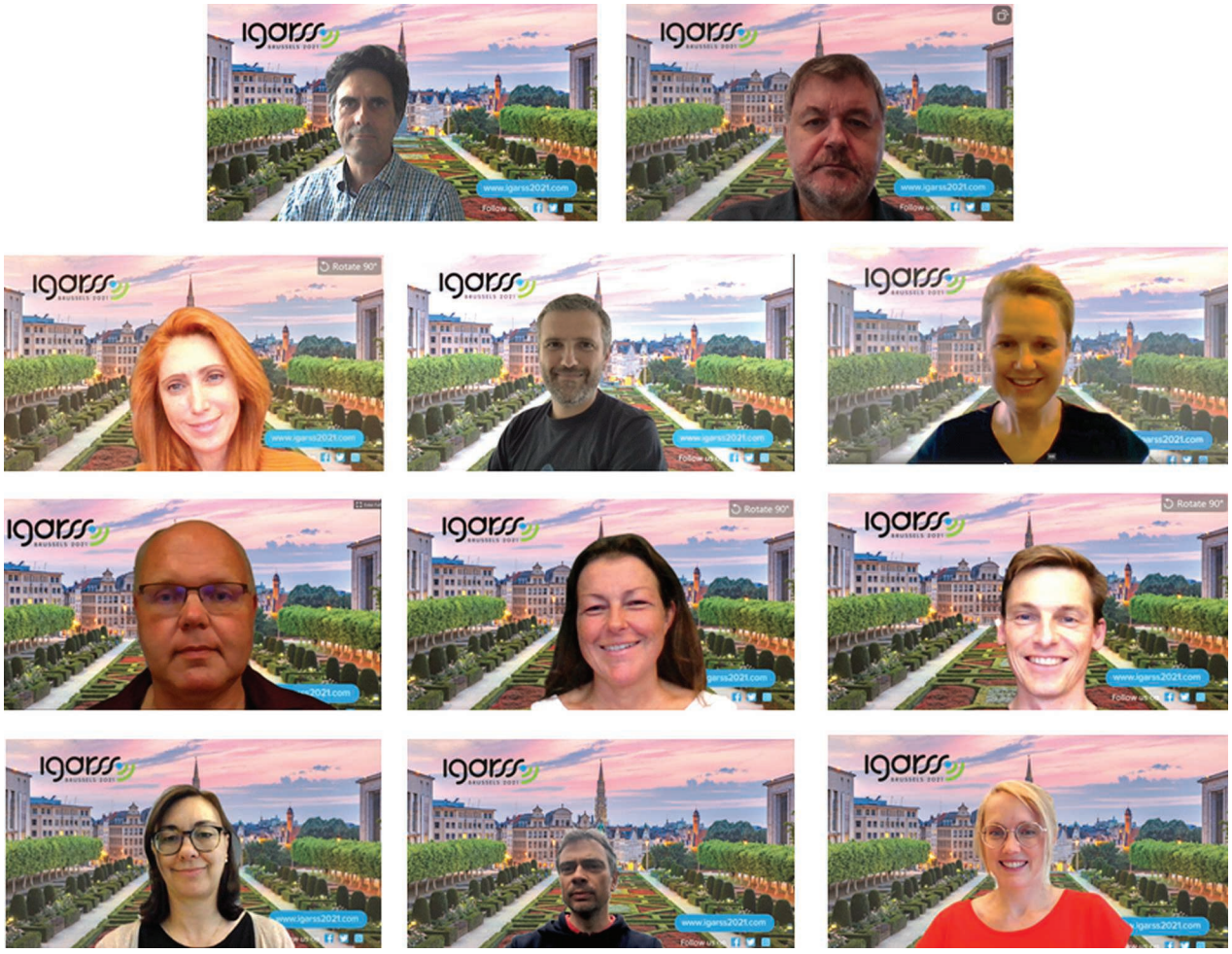


FIGURE 12. The IGARSS chairs and organizers. Top row: Ramon Hanssen and Joost Vandenabeele. Second row: Michal Shimoni, Devis Tuia and Sindy Sterckx. Third row: Jeroen van Gent, Séverine Desmet, and Bart Deronde. Bottom row: Ils Reusen, Jean-Christophe Schyns, and Evelyn Stynen.