Report from the 2025 COSPAR Capacity Building Workshop on the International Reference Ionosphere and NeQuick – Improving the Representation of the Real-Time Ionosphere

Dieter Bilitza and Bruno Nava

The 2025 COSPAR Capacity-Building Workshop (CCBW) on the International Reference Ionosphere (IRI) and NeQuick was held at the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste, Italy, from 29 September to 10 October 2025. The workshop was supported by the Committee on Space Research (COSPAR), ICTP, and the United Nations Office for Outer Space Affairs (UNOOSA) through the International Committee on GNSS (ICG). NASA provided additional support for the participation of two lecturers from the United States.

The official announcement of the workshop was released in early 2025, and 108 applications were received from students and early-career researchers representing 29 countries, predominantly from Africa. Based on evaluations of the curricula vitae, letters of recommendation and submitted research plans, the organizing committee selected 35 applicants for financial support. The final group of participants came from Algeria, Argentina, Brazil, Burkina Faso, China, the Democratic Republic of the Congo, Cyprus, Egypt, Ethiopia, Ghana, India, Kenya, Nigeria, Pakistan, Senegal, South Africa, Thailand, Uganda, and the United Kingdom. With 17 female and 16 male students there was a good gender balance. Accommodation for all students and lecturers was provided in the ICTP guesthouses located on the center campus, within a short walking distance of the workshop venue, the Budinich Lecture Hall in ICTP's Leonardo Building.

The workshop was opened with welcome remarks by the Workshop Organizers Bruno Nava (ICTP), Dieter Bilitza (COSPAR), Sharafat Gadimova (UNOOSA) and John Bosco Haburalema (South African National Space Agency, SANSA). A special opening lecture was delivered by Inae Jung (Korea Aerospace Research Institute, KARI), who introduced the students to KARI's mission, satellite programs and recent activities.

Lectures and First Week Activities

During the first week, the students were introduced to the fundamentals and recent advances in observation techniques and modelling approaches for Earth's ionosphere through a combination of tutorials, lectures, and hands-on demonstrations. A central objective of the workshop was to familiarize the students with access to ionospheric data sets and models, enabling them to continue their research interests at their home institutions. The teaching program was led by ten lecturers:

- Dieter Bilitza (George Mason University, USA): Introduction to IRI and recent developments
- Bruno Nava (ICTP): Introduction to NeQuick and recent developments
- Ivan Galkin (University of Massachusetts Lowell, USA): Ionosondes, the measurements they take, and access to ionosonde data

- Andrzej Krankowski (University of Warmia and Mazury, Poland): GNSS data for ionospheric studies and data access
- Shunrong Zhang (MIT, USA): Incoherent scatter radar and ionospheric studies and data access to incoherent scatter data
- Vladimir Truhlik (Institute for Atmospheric Physics, Czech Republic): Representation of plasma temperatures and ion composition in IRI and access to satellite data
- Min-Yang Chou (NASA/GSFC/CCMC, USA): General description and introduction to CCMC and access to IRI at CCMC
- Yenca Migoya-Orue (ICTP): Ionospheric modelling using machine learning and access and usage of NeQuick
- Lucilla Alfonsi (INGV, Italy): Introduction to ionospheric irregularities studies
- John Bosco Habarulema (SANSA, South Africa): Global 3-D electron density reconstruction by combining ionosonde and radio occultation datasets

Student teams and advisors taking a picture-break from study work.

Four students were unable to attend due to health or visa issues. The students were divided into seven teams; each assigned a specific research problem to be addressed during the two-week workshop. Each team had one of the lecturers as their main advisor, but was free to ask help from other lecturers as well. Each project was related to an ionospheric modelling problem that required the students to review the provided problem-related papers, to download data from some of the sites explained in the tutorials, and run some of the online models shown during the hands-on demonstrations. The seven projects were: (1) Representation of the occurrence probability of spread-F in IRI for different longitude sectors; (2) Studying plasma bubbles with Swarm and GNSS data; (3) Study of the relationship between equatorial spread-F occurrence rate and vertical plasma drift; (4) Millstone Hill Incoherent scatter radar observations during April 2024 and comparison with IRI and NeQuick; (5) Real-time MUF monitoring and alert generation for aviation ground dispatchers and pilots; (6) TEC data ingest into NeQuick and foF2 prediction; (7) Use of Machine Learning (ML) techniques for modelling the sporadic-E occurrence probability.

At the end of the first week each team presented prelimenary results and received feedback from the lecturers.

Group picture of students and lecturers

Excursion to the Grotta Gigante

An excursion was organized on Wednesday afternoon of the second week to the Grotta Gigante which is located on the Italian side of the Trieste Karst (Carso) and about a 20-minute bus ride north of ICTP. It is one of the world's largest show caves. Its cathedral-size space and the constant temperatures throughout the year have led to the placement of scientific instruments in the cave, including two horizontal pendulums which hang down from about 100 m (330 ft), and are the longest geodetic pendula in the world.

Excursion to the Grotta Gigante – 500 steps down and up – pendulums in the background.

IRI/NeQuick Expert Meeting

The CCBW meeting was combined with an IRI/NeQuick expert meeting during the second week offering the students the opportunity to attend an international scientific conference – often for the first time - and an opportunity to present a talk or poster at the meeting about their own

research. Twelve of our students gave talks and seven presented posters. It was also a great opportunity to talk about potential post-doc positions. The meeting focused on “Improving the Representation of the Real-Time Ionosphere” and was attended by 65 participants, featuring 45 talks and 10 posters across sessions covering “High Latitude Studies”, “Model Comparisons and Assessment”, “TEC Algorithms and Radio Occultation”, “Real-Time IRI and NeQuick”, “Plasma Temperatures, Ion composition and Ion Drift”, “Lower Ionosphere”, “Topside and Plasmasphere”, “Modelling Storms and Irregularities”, “New Inputs for IRI and NeQuick”, “Posters”, and “Final Discussions”.

Group picture of the IRI workshop participants.

Outcomes and Awards

During the Final Discussions session several improvements for the next version of the model were discussed. This includes a new model for the extension of IRI into the plasmasphere and an improved version of the electron temperature model. Of special interest were improvements to the newly included global model for the occurrence probability of a Spordic E layer. These intense ionization enhancements in the E-region, can degrade and severely disrupt the propagation of radio signals. One of the student projects was investigating machine learning solutions to the modeling problem. One of the newest models and a potential improvement candidate for IRI is the GEMSOR model that Dr. Emmons and his collaegues at the US Air Force Institue of Technology had developed based on GNSS radio occultation data and ionosonde observations. Dr. Emmons was not able to attend in person due to the US Government shutdown but he described the latest developments via video presentation. Much activity is focussed on modelling the occurrence probability of scintillations, spread-F and plasma bubbles. Two student teams worked on related problems and one student (Harold Safary, Kenya) reported on the results of his COSPAR Capacity Building Fellowship at the Leipniz Institute for Atmospheric Physics (IAP) in Kuehlungsborn, Germany, where he worked on including the plasma bubbles model deceloped at IAP into IRI. Very promising also the modelling work at Wuhan University (China) led by Chao Xiong.

One new member was invited and accepted to join the IRI Working Group: Yenca Migoya-Orue (ICTP, Italy). She was a very active member of the local organizing team for the workshop and will help to further the use of machine learning for IRI modelling. Chao Xiong presented a proposal for a COSPAR Capacity Building IRI Workshop in 2027 at Wuhan University in China, which was welcomed by the IRI Working Group.

The students continued their work during the second week and presented their project results at the end of the second week to the full IRI Workshop audience. Three senior scientists served as judges evaluating the scientific quality, results, and presentations of the seven groups. All seven teams received Mandana Sigaroudi Young Scientist Awards, which, thanks to the generous contribution by the award sponsor, include monetary prizes ranked from first to seventh place. In addition, the IRI Young Female Scientist Award was presented for the first time. The awardee was selected by a panel of three senior female scientists and was presented to Pires Moraes Santos R. Godoy (Brazil) in recognition of her excellent scientific contributions and collaborative leadership during the workshop.

The 2025 COSPAR Capacity-Building Workshop successfully advanced technical training in ionospheric modeling, strengthened international collaboration, and provided a platform for young scientists to contribute directly to the future development of IRI and NeQuick.

Left picture: **1rst Place Team** (from left to right): Tshiangomba Reagan Kasonsa (Congo DR), Paul Krishnendu Sekhar (India), Victoria Lourdes Mariana Abigail (Argentina), Ndiaye Sira (Senegal). **PROBLEM:** Spread-F climatology in IRI is limited to the American sector. Study other longitude sectors. (D. Bilitza, Advisor).
Right picture: **2nd Place Team** (from left to right): Shunrong Zhang (Advisor), Biswas Trisani (India), Babirekere Hellen (Uganda), Nakolemda Roger (Burkina Faso), Ogwala Aghogho (Nigeria), Waweru Mary Dusabe (Kenya). **PROBLEM:** Millstone Hill Incoherent scatter radar observations in April 2024 including solar eclipse and comparison with IRI and NeQuick averages and variability


Left picture: **3rd Place Team** (from left to right): Sulaiman Yushau Muhammad (Nigeria), Kabore Issiaka (Burkina Faso), Abuelezz Ola Ahmed Mustafa (Egypt), Ateede Jesca Rebecca (Uganda). **PROBLEM:** Studying plasma bubbles with Swarm and GNSS data (Advisors: Lucilla Alfonsi, Vladimir Truhlik)
Right picture: **4th Place Team** (from left to right): Kyamulesire Bruno (Uganda), Yassen Ahmed Mahmoud Hassan (Egypt), Ather Fatima (Pakistan), Safary Harold Lumumba (Kenya).
PROBLEM: Use of Machine Learning (ML) technique for modelling the sporadic-E occurrence probability. (Advisors: Yenca Migoya-Orue, Vladimir Truhlik)


Left picture: **5th Place Team** (from left to right): Ojo Olakunle Lawrence (Nigeria), Bazie Nongobsom (Burkina Faso), Pires Moraes Santos R Godoy (Brazil), Namniwong Thapanan (Thailand). **PROBLEM:** TEC data assimilation into NeQuick model (Advisors: Bruno Nava, Andrzej Krankowski).
Right picture: **6th Place Team** (from left to right): Lomotey Solomon Otoo (Ghana), Gul Bushra (Pakistan), Gurney Emma-Claire (UK), Yan Xu (China). **PROBLEM:** Real-time MUF monitoring and alert generation for aviation ground dispatchers and pilots (Advisor: Ivan Galkin)

Left picture: **7th Place Team** (from left to right): Hegy Mostafa Elsayed Abdelhafez (Egypt), Maundu Nahum Ndunge (Kenya), Thaganyana Golekamang Piet (South Africa), Benghanem Karima (Algeria), Maichuen Samatchaya (Thailand). **PROBLEM:** Study the relationship between ESF occurrence rate and vertical drift (Advisors: Min-Yang Chou, John Bosco Habarulema).
Right picture: Pires Moraes Santos R Godoy (Brazil) receives the IRI Young Female Scientist Award (from left to right: Feza Arikan, Pires Moraes Santos R Godoy, Yenca Migoya-Orue, Dieter Bilitza).