last two years, two training programmes on AST (conducted by ICAR-IVRI and ICAR-CIFT (ICAR-Central Institute of Fisheries Technology)) and two training programmes on WHONET (conducted by ICAR-NBFGR and ICAR-IVRI) were organized by INFAAR in collaboration with FAO, India to train 53 participants on AMR-related laboratory procedures and data management. Besides, a specialized FAO–ICAR training on Assessment Tool for Laboratories and Antimicrobial Resistance Surveillance Systems was organized at ICAR-CIFT for skill upgradation of 22 scientists of INFAAR. The scientists of INFAAR have participated in the 'FAO-NACA regional consultation on AMR in aquaculture' held in Bangkok, Thailand from 4 to 7 September 2018 and an international training on 'Standardized and harmonized surveillance methods for AMR in food animals in South Asia' held at Bangkok from 28 to 31 May 2019. These have helped INFAAR in developing a skilled workforce for AMR analysis.

The issue of AMR also needs to be addressed by raising awareness amongst all stakeholders on implementing good practices to reduce the use of antimicrobials. Every year INFAAR creates awareness on 'judicious use of antibiotics' among the public, especially during 'World Antibiotics Awareness Week' from 18 to 24 November in different parts of the country. INFAAR has launched a dedicated website (www.infaar.icar.gov.in), which provides the latest information on AMR in the country. An Advisory Board established by the ICAR/Department of Agricultural Research and Education (DARE) is regularly guiding the functioning and activities of INFAAR.

INFAAR is working towards safe food production for human consumption without the risk of transmitting AMR to humans through the food production cycle. Safe food production without AMR risk will promote human and animal health, and a clean environment. The data generated by INFAAR will lead to the identification of strategies to prevent and reduce the development and spread of AMR in aquaculture and food animals. Successful implementation of INFAAR will be a key component NAP on AMR for the protection of human health, animal health and food safety in India.

1. O'Neill, J., *Review on Antimicrobial Resistance*, Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations, London, 2014; https://amr-review.org/
2. Laxminarayan, R., Sridhar, D., Blaser, M., Wang, M. and Woolhouse, M., *Science*, 2016, **353**(6302), 874–875.
3. Van Boeckel *et al.*, *Proc. Natl. Acad. Sci. USA*, 2015, **112**, 5649–5654.
4. Rathore, G., *Standard Operating Procedures: Network Programme on Antimicrobial Resistance in Fisheries and Aquaculture*, ICAR-NBFGR Publication, Lucknow, 2019, pp. 1–95.

ACKNOWLEDGEMENTS. We thank FAO, India and USAID for providing technical support to INFAAR over the years. We also thank ICAR and all eight ICAR-Fisheries research institutions for providing the necessary facilities and support to the fisheries component of INFAAR.

Gaurav Rathore* and **Kuldeep K. Lal,** ICAR-National Bureau of Fish Genetic Resources, Lucknow 226 002, India; **Rajesh Bhatia,** Former Regional Technical Advisor on AMR, FAO, New Delhi 110 002, India; **J. K. Jena,** Indian Council of Agricultural Research, Krishi Anusandhan Bhawan-II, Pusa, New Delhi 110 012, India.
*e-mail: Gaurav.Rathore@icar.gov.in

MEETING REPORT

Global seismology and tectonics*

A twelve-day 'International Virtual Workshop on Global Seismology and Tectonics' was organized recently to bring national and international experts together and boost the morale of the students and researchers during the COVID-19 pandemic by providing opportunities to interact with eminent scientists in the domain of seismology and tectonics.

G. Narahari Sastry (Director, CSIR-North East Institute of Science and Technology, Jorhat), who inaugurated the workshop, emphasized the importance of computational technology in every branch of science and research. The workshop was chaired by J. R. Kayal (former Deputy Director General, Geological Survey of India, Kolkata). About 1000 participants from 30 countries registered for the event. Fifteen eminent speakers from different geoscience institutions delivered lectures and each of the lectures was attended by about 800 participants. The lectures by the keynote speakers covered all major aspects of seismology. Sixteen lectures were delivered during the workshop and are briefly highlighted here.

Andrew J. Michael (United States Geological Survey (USGS)) gave a talk on 'Why it is hard to count earthquakes: estimating catalog completeness'. He discussed that it is now much easier to acquire earthquake event information from institutions such as the USGS or the International Seismological Centre (ISC), than in the past. While the advances are positive, it also means that researchers may not be in contact with the catalogue creators, who can advise them on its strengths and weaknesses. Over time, seismic networks have also become much better with more stations, higher quality seismometers, digital recording and improved analysis methods. However, it is important to understand how these advancements affect earthquake catalogs.

Michael also discussed 'The Poisson assumption: applications in spite of clustering'. He discussed how the Poisson probability distribution is frequently used to describe the temporal behaviour of

*A report on the International Virtual Workshop on Global Seismology and Tectonics (IVWGST-2020) organized by the CSIR-North East Institute of Science and Technology, Jorhat, Assam, from 14 to 25 September 2020.

earthquakes. It is the basis of probabilistic seismic hazard analysis (PSHA) and a frequent null hypothesis for testing earthquake prediction and forecasting methods. However, the clustering of seismicity, which has been noted from the time of the earliest earthquake records, violates the Poisson assumption that earthquakes are independent events.

Walter D. Mooney (USGS) spoke about the 'Tectonics and seismicity of Indonesia and Southeast Asia'. He mentioned that South Asia is ideal to study plate tectonic processes, because it includes the greatest diversity of plate boundaries on the Earth. Three major plates converge in South Asia, viz. the Indo-Australian, Pacific and Eurasian. In addition, there are several smaller plates, such as the Philippine Sea, Carolina and Banda Sea. Despite this complexity, there are large portions of Indonesia and Southeast Asia that have a relatively simple tectonic setting. Three prizes named after three Indian Nobel laureates, viz. C. V. Raman (1930 Nobel Prize winner in physics), S. Chandrasekhar (1983 Nobel Prize winner in physics) and Rabindranath Tagore (1913 Nobel Prize winner in literature) have been personally set up by Mooney for the following research problems:

(i) Why ocean–ocean subduction is more complex and shorter-lived than ocean–continent subduction?

(ii) What is the physics behind the linear decrease in the number of earthquakes to a depth of about 350 km followed by an increase in the number of earthquakes in the Java–Sumatra subduction zone?

(iii) How strike–slip faulting causes tsunamis?

Djordji Grujic (Dalhousie University, Canada) presented a lecture on 'Spatial and temporal interplay between "viscous" and "brittle" deformation processes in the Himalayan mega thrust', where he discussed the continuum of stress, strength, slip and creep in the subduction zone. He also discussed how viscoelastic deformation, poroelasticity and ductile flow lead to dispersion and attenuation of seismic waves down dip of the seismogenic zones.

Nicholas van der Elst (USGS) in his lecture on 'Forecasting aftershocks with the epidemic type model', explained that it is possible to make probabilistic assessments of aftershock hazards based on past regional sequences and the specifics of an ongoing sequence. Aftershocks follow well-established statistical rules regarding the distribution of number, time of occurrence and magnitude. Aftershock forecasts provide situational awareness, increase public resilience, and help prioritize response and recovery operations.

Ramesh Singh (Chapman University, USA) presented a lecture on 'Ground, borehole and satellite observations for search of reliable earthquake precursors'. He discussed the use of surface, geophysical, borehole and multi-satellite sensors in obtaining information about ocean, atmosphere, ionosphere and meteorological parameters in the search of a reliable precursor(s) of an impending earthquake. Further, he stressed the need for an integrated approach to the mitigation of earthquake impacts in areas prone to high seismicity such as North East (NE) India.

R. B. S. Yadav (Kurukshetra University, India) described 'Coulomb stress modelling and seismicity triggering: a perspective on future seismic hazard' and discussed how earthquake interactions are a fundamental feature of seismicity, leading to earthquake sequences, clustering and aftershocks. He argued that Coulomb stress transfer could be used to gain a deeper understanding of earthquake occurrence and a better description of probabilistic hazard.

Susan E. Hough (USGS) presented a lecture on 'Earthquake ground motions and damage: the long and the short of it'. She mentioned that seismologists have long known that shallow geological structures like soft shallow sediments and deep sedimentary basins can have a profound effect on ground motions. She used basic physics to illustrate how low-impedance layers amplify the level of shaking, often at particular resonance frequencies.

J. R. Kayal presented an overview of the 'Recent strong and large intraplate earthquakes in India'. He elaborated upon the application of aftershock relocation based on homogeneous and simultaneous inversion methods, fault plane solutions and 3D seismic images to identify the seismogenic faults/source zones and depth of these earthquakes. He presented evidence that fault intersections are the most likely source zones for the continental region events.

Speaking about 'Complex tectonics of NE India', Saurabh Baruah (CSIR-NEIST) established that understanding the seismic behaviour of the complex tectonic domain of NE India is extremely frustrating because there are no expressions of surface ruptures showing the location of the two great earthquakes of the region, viz. 1897 (*Mw* 8.0) and 1950 (*Mw* 8.6). A mismatch between slip rate and co-seismic uplift indicates the existence of blind faults in potential source zones of the region.

Mehdi Zaré (International Institute of Earthquake Engineering and Seismology, Iran) delivered a talk on 'Why seismic hazard zoning maps are uncertain and should be revised using new seismic source modelling'. He reviewed the controlling factors for seismic hazard analysis and earthquake source uncertainty. He stated that after each major earthquake, the seismic source determinations, seismicity parameters and ground motion models are expected to be modified, and there are always discussions on the reliability of the seismic hazard zoning maps and a comparison between the recorded and previously assessed ground motions.

Tahmeed M. Al-Hussaini (Bangladesh University of Engineering and Technology), described the 'New seismic design provisions for updated Bangladesh National Building Code (BNBC-2017) with reference to seismic hazard assessment studies'. He discussed that the seismic risk of Bangladesh was addressed through incorporation of seismic design guidelines and a seismic zoning map. He mentioned that major progress has been made worldwide in earthquake engineering and different building codes have been upgraded accordingly. He made a case to revise the Bangladesh earthquake engineering design provisions, including a new seismic zoning map for that country.

Sebastiano D'Amico (University of Malta) presented a lecture on 'The challenge of computing seismic hazard maps and incorporating site effects'. He discussed how seismic hazard assessment may be either probabilistic (PSHA) or deterministic (DSHA). PSHA is a statistical approach that considers a long time-history of seismic activity in the region around the source zone; a characterization of earthquake sources using points, lines, or rupture areas; and temporal patterns of seismicity and energy attenuation models. DSHA, on the other hand,

considers a likely earthquake source scenario, and numerically computes the ground motion due to this source at a chosen remote site of interest.

A. A. Adepelumi (Obafemi Awolowo University, Nigeria) presented a lecture on 'seismicity of Africa'. He discussed the tectonic settings, stress state, and seismicity of the continent. He asserted that seismicity of southern Africa is moderate, of shallow origin and in most cases difficult to correlate with geologic features. Though the region is considered to lie in a stable continental region, both natural and mining-induced earthquakes are reported by the Council for Geoscience of South Africa (CGS), USGS, ISC and the Bulawayo Seismological Station in Zimbabwe.

V. K. Gahalaut (CSIR-National Geophysical Research Institute, India) presented a talk on 'Tectonics of Indo-Burmese arc'. He explained that earthquakes in NE India occur in response to the India–Eurasia and India–Sunda plate interactions in the north and east respectively. The region exhibits interplate, intraplate, intraslab and intrawedge earthquakes. Earthquakes in the Indo-Burmese arc occur in response to the partitioning of the India-Sunda motion along two distinct boundaries.

Imitiaz A. Parvez (CSIR-Fourth Paradigm Institute (CSIR-4PI), India) in the final talk entitled 'Earthquake hazard studies in India' discussed the importance of seismic zonation and microzonation studies in India and adjacent areas, which have been beneficial, not only for science but also for society. He described seismic zonation and microzonation from historical seismicity and the present application of seismic hazard assessment in India through probabilistic and deterministic approaches.

The closing ceremony of the workshop was chaired by Ramesh Singh and co-chaired by Saurabh Baruah. Baruah briefly summarized the proceedings of the workshop. Narahari Sastry acknowledged all the keynote speakers and summarized the major aspects of the workshop. Keeping the interests of the global audience in mind, all the lecture sessions have been recorded and uploaded to the YouTube channel of CSIR-NEIST (https://www.youtube.com/channel/UCT6mR4LjRj9rIaYyoHuDjfA). This is perhaps the first virtual event to launch an e-abstract volume compiling 21 abstracts from the participants and 16 lecture abstracts by keynote speakers, which can be downloaded from http://www.rrljorhat.res.in/Final%20e-Abstract%20Volume%20IVWGST%202020.pdf. The intuitive lectures broadly covered classical and contemporary fronts of seismology and tectonics, and immensely benefited the students and researchers. All the participants were provided with an e-certificate of participation. All the keynote speakers were honoured with a note of appreciation and acknowledgement from the organizing committee. The successful execution of this workshop has encouraged the organizers to consider conducting periodic workshops of this kind in the near future.

Santanu Baruah*, Chandan Dey and **G. Narahari Sastry,** CSIR-North East Institute of Science and Technology, Jorhat 785 006, India; **Andrew J. Michael,** United States Geological Survey (USGS), Moffett Field, California 94035, USA.
*e-mail: santanub27@gmail.com