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Guest Editorial

The International Union of Geodesy and Geophysics (IUGG) is an international non-governmental organization dedicated to the scientific study of the Earth and its space environment using geophysical and geodetic techniques.

IUGG was established in 1919 by 9 founding member countries to promote activities of 10 already-existing international scientific societies dealing with geodesy, terrestrial magnetism and electricity, meteorology, physical oceanography, seismology, and volcanology. During the period 1919 to 1939 the number of member countries increased to 35.

India joined IUGG in 1947. The Indian National Science Academy (INSA) is the adhering body for ICSU (now ISC) and IUGG in India. The affairs of IUGG are the responsibility of the Indian National Committee for IUGG and IGU.

The year 2019 is the centennial year of the formation of the International Union of Geodesy and Geophysics (IUGG). In 2017, a decision was made to bring out a special issue of Proceedings: Indian National Science Academy (P-INSA) to commemorate the centennial year 2019 of IUGG. The purpose of this volume would be to show case IUGG related work having been carried out in India. The members of the IUGG&IGU Indian National Committee took up the responsibility for writing articles corresponding to the 8 constituent International Associations of IUGG. The present volume includes 10 articles, one each for the eight Associations with the exception of International Association of Seismology and Physics of the Earth's Interior (IASPEI) where there are two articles, and a reprint of "Koyna, India, an Ideal site for Near Field Earthquake Observations" from the Journal of Geological Society of India. Contents of the "Encyclopedia of Solid Earth Geophysics" published by Springer in 2011 are also placed in this volume.

International Association of Cryospheric Sciences (IACS)

Baldev Arora and his colleagues in their article "**Himalayan Cryosphere: Appraisal of Climate Glacier Inter-linkages**" have reviewed the growth of cryospheric research in Himalaya, India and its importance in climate change related studies. Examining the snout and mass balance data indicates increased rates of glacier recession during 1970's and 1980's specifically the Central and North-East Himalaya. This is consistent with the global trend. The recession of the glaciers is attributed to increase in anthropogenic emissions of the Green House Gases. Contrary to this trend the glaciers in Karakorum region, Indus Basin are characterized by marginal growth or stagnation. A slowdown in glacier retreat since 1990's is observed along the entire Himalayan arc. An important issue is to forecast the melt water contribution to perennial rivers is of utmost importance for a variety of agricultural, and other social issues. A road map is presented to improve accuracy of anticipated contribution of melt water to the rivers. It is proposed to set up a National Institute of Glaciology to better address glacier related issues, particularly in the Himalayan region.

International Association of Geodesy (IAG)

Srinivas and Tiwari in their article "**Gravity and geodetic studies in India: historical observations and advances during the past decade**" have given a glimpse of how gravity and geodetic work started in India. The Great Trigonometric Survey (1790-1850) defined the geodetic reference frame. Gravity and geodetic observations in the Himalayan region during 1830 to 1843 led to the development of the concept of 'Isostasy', indeed a phenomenal contribution from India. Detailed regional gravity surveys, including pendulum observations started in 1950's. The Survey of India established the Indian national reference gravity station at Dehradun tied up with Potsdam gravity base sometimes in 1948. Taking into account

of all the gravity stations in the country, the National Geophysical Research Institute undertook publishing a series of gravity maps of India in 1975. The Geological Survey of India launched National Geophysical Mapping program during 2002/2003 with an objective to generate gravity and magnetic responses in potential areas of mineral exploration. In the recent years detailed gravity surveys including airborne gravity gradient surveys are undertaken to comprehend subsurface mass distribution and mass variability. Other focus area have been refining of the geodetic datum, continental deformation and exploration for resources.

International Association of Geomagnetism and Aeronomy (IAGA)

Manglik in his article "**Research Highlights of the Indian Contributions to Geomagnetism and Aeronomy in the 21st Century**" has provided a historical background of the development of Geomagnetism and Aeronomy globally and in India. Apparently Chinese had discovered existence of magnetism more than two millennium BC. However, the first magnetic compass in China dates back to 1088 AD. In Europe first magnetic compass is reported back to 1190. The first comprehensive description of geomagnetic field was published in 1600. There was quantum jump in magnetism related work in the 19th century. The first magnetic observatory in India was established in Madras in 1792 and the Colaba Observatory at Bombay was established in 1841 ushering the era of continuous observations. In 1904 Alibag Observatory in Bombay was established. Colaba and Alibag observatories provide the longest series of magnetic data anywhere in the world. In the 21st century a considerable amount of work has been carried out on the theory of planetary magnetic field, paleomagnetism, rock and environmental magnetism, equatorial plasma bubble, space weather and geomagnetic storms. In 2014 an IAGA Observatory workshop with 93 observers from 33 countries was organized at the National Geophysical Research Institute, Hyderabad. Magnetic precursors to earthquakes are being investigated through operation of a number of multi-parametric observatories. High resolution heliborne TEM along with magnetics has been used for exploration of ground water and atomic minerals. Future opportunities include Indian space missions for planetary exploration, probing of Indian lithosphere and geo-resource exploration.

International Association of Hydrological Sciences (IAHS)

Arora and Tiwari, in their article "**Hydrological Studies in India during last decade: A Review**" provide a glimpse of the one of the most essential commodity for the survival of humanity: water; variation of water requirements and its availability, large data sets generated and their analyses for appropriate utilization and preservation of this fast depleting water resources.India has a huge hydrological and climatic variability with Thar Desert in Rajasthan getting less than 250 mm rain annually to Mawsynram in Meghalaya getting 11870 mm annually. The demands for water also vary substantially from one region to another. The total annual average rainfall over India and river flow are estimated to be ~1950 km^3, while the utilizable surface water is estimated to be 690 km^3. According to estimates in 2011, the total ground water resources and availability are 433 km^3 and 398 km^3. Some 83% water resources are used for agriculture, 7% for domestic use, 2% for industry, 1% for energy and 7% for all the rest of uses. Using the data from Gravity Recovery and Climate Experiment (GRACE), it is possible to investigate spatio-temporal variations in the total terrestrial water storage and decipher whether in a particular geographical region there is depletion or addition of the water resource. It has been found that north India aquifers are losing, particularly in the Ganga River Basin. "Winning, Augmentation, Renovation" (WAR) is the project launched in 2009 with an aim to find inexpensive methods for converting the saline water into fresh water, harnessing and managing Monsoon water, to manage the flood water and implementing rain water harvesting. In a nutshell, a lot of work has been done in the recent years in India to understand and improve ground water and surface water utilization. In 2009, the National Geophysical Research Institute hosted a very successful Assembly of IAHS at Hyderabad, with the participation of ~1200 scientists from all over the world.

International Association of Meteorology and Atmospheric Sciences (IAMAS)

Maharana and Dimri in their article "**Monsoon: Past present and Future**" have provided an overview of

the monsoon related studies in India. They note that summer months contribute to 80% of the total rainfall in India. The spatial and temporal variation of Indian Summer Monsoon (ISM) has deep socio-economic implications for the people living in the Indian sub-continent. Monsoon related investigations got initiated way back in the British era. Better observational facilities, computational facilities, and models have improved Monsoon forecast considerably. However, a lot more needs to be done as an improvement in ISM forecast directly impacts agriculture, flood control, hydroelectric power generation etc. The authors emphasize on collection of better quality data, improvement of model dynamics, use of four dimensional data assimilation, use of better air-sea interaction coupled models and use of ensemble model for improving ISM forecast. They also emphasize on timely dissemination of the forecast.

International Association of Physical Sciences of the Oceans (IAPSO)

Satish Shenoi is the corresponding author of the article "**Physical Sciences of the Ocean: A report to IAPSO/IUGG**" with Prerna, Paul and Francis. To convey the amount of work carried out in IAPSO related work in India in the 21st century, they have put together statistics of publications. In the first 18 years of the current century, around 2300 scientific papers were published involving around 4800 scientists. In these publications collaborative work was carried out with 44 countries. They observe that deployment of Acoustic Doppler Current Profilers (ADCPs) and data from Ocean Data Buoys have helped improving the understanding of Indian Ocean variability and air-sea interaction processes. Indian National Center for Ocean Information Services (INCOIS) set up India's first Operational Ocean Forecast System in 2010. It is very well received. Discovery of Indian Ocean Dipole in 1990's and Equatorial Indian Ocean Oscillation in early 2000's gave an incentive to research on tropical coupled air-sea interaction processes. Potential fishing zone (PFZ) advisories that started in 1990's, have been found very useful by the large fishermen community on the east and west coast of India. Based on sea surface temperatures and chlorophyll content sensed by satellite, the advisories are further improved using ocean circulation and marine ecosystem parameters. The other area commented upon by them is the coastal effects of 2004 Indian Ocean Tsunami and development of the Indian Tsunami Early Warning System.

International Association of Seismology and Physics of Earth's Interior (IASPEI)

There are three articles covering various facets of IASPEI in India. Prakash Kumar in his article **"Recent Seismological Investigations in India"** has discussed seismogenesis and seismotectonics of Himalaya, Burmese-arc, Andaman-Nicobar subduction zone; seismicity of stable continental region (SCR) of India including reservoir triggered seismicity at Koyna, near west coast of India; setting up of the Indian Tsunami Early Warning System (ITEWS), which was established consequent to the occurrence of the 26 December 2004 Mw 9.2 Sumatra earthquakes and the resultant tsunami that claimed over 220,000 human lives. ITEWS was set up in a record 30 months time and was functional by September 2007. It is now considered among the best in the world. Prakash Kumar also discusses the efforts made in India in the recent years to develop an earthquake resilient society. There is also information about the seismological networks in India.

Kalachand Sain has devoted his article "**Controlled Source Seismology in India in the 21st Century**" to the beginning of controlled source seismic (CSS) studies in 1970's in India and how they have progressed over the last ~50 years. Most important geological units of India have been covered by CSS and useful structural details have been highlighted. Investigation for possible Mesozoic sediments that could be petroliferous overlain by the Deccan Volcanic basalt has been pointed out. The results of CSS have been later confirmed by actual drilling. Remarkable success has been achieved in application of CSS in detecting, delineating and assessing the resource potential of gas-hydrates in the off shore regions of India. The estimated amount of gas hydrates is huge: only 10% production of this vast resource in the exclusive economic zone of India can meet energy requirement of the country for the next 100 years.

The third article is a reprint from the Journal-Geological Society of India entitled "**Koyna, India, an Ideal Site for Near Field Earthquake Observations**" written by Harsh Gupta in collaboration with several scientists. Koyna, with a

magnitude M 6.3 reservoir triggered earthquake on 10 December 1967 is a unique site of reservoir-triggered seismicity (RTS), where triggered earthquakes got initiated soon after the impoundment of Shivaji Sagar Lake in 1962. RTS has continued till now with the largest RTS event globally in 1967 and several thousand smaller earthquakes including 22 of $M \geq 5$. Common characteristics of RTS events have been worked out that help them to be discriminated from the normal events (not associated with water reservoirs). A 3 km deep pilot borehole has been completed for near field study of earthquakes. Measurements carried out in and around Koyna are leading to setting up of a 7 km deep borehole laboratory: the first of its kind anywhere in the world.

International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)

Ray and Parthasarathy in their article "**Recent Advancement in Studies of Deccan Traps and Its Basement; Carbonatites and Kimberlites - An Indian Perspective in Last Five Years**" have attempted to provide information on the research carried out on Deccan flood basalts, Kimberlites and Carbonatites over the past few years. The issues addressed include origin of Deccan Traps and their composition and age distribution; and origin, disposition, chronology, petrology and geochemistry of Indian Carbonatites. It is inferred that the primary magmas for the Indian Carbonatites originated from sub-continental lithospheric mantle. They have also underlined usefulness of several secondary minerals in Deccan volcanic rocks.

Several senior positions have been held by Indian scientists in IUGG Bureau and Finance Committee. These include K R Ramanathan, President (1954-1957); Devendra Lal, President (1983-1987); Harsh Gupta, President (2011-2015), Vice President (2007-2011), Bureau Member (1999-2003 and 2003-2007); Vinod Gaur, Member, Finance Committee (1995-1999 and 1999-2003); Virendra Tiwari, Member, Finance Committee (2015-2019).

In the recent past the National Geophysical Research Institute (NGRI) hosted the International Association of Hydrological Sciences Assembly at Hyderabad in 2009. The joint assembly of IAGA and IASPEI shall be also hosted by NGRI in 2021.

It is indeed a great pleasure to acknowledge efforts of all the members of the Indian National Committee for IUGG and IGU for contributing their articles timely to make it possible to bring this volume in time to coincide with the IUGG General Assembly scheduled at Montreal, Canada in July 2019. Thanks are also to the reviewers, namely Rasik Ravindra, C V Sangewar, M Radhakrishna, Maj Gen (Dr.) B Nagarajan, B R Arora, P Rajendra Prasad, Shishir K Dube, B N Goswami, Dipankar Sarkar, J R Kayal, T Radhakrishna for their comments on the papers, which were very constructive. In the end I would also like to thank Prof Subhash Chandra Lakhotia and Prof Sanjay Puri, Chief Editors of P-INSA. Ms Richa and Ms Seema of Editorial Office of P-INSA are acknowledged for their help in bringing out this volume. Ms. M Uma Anuradha and Ms. K Mallika at the National Geophysical Research Institute, Hyderabad helped me in researching for this review volume.

On behalf of the entire Indian community of geophysicists and geodesists, we wish a very successful centennial year to IUGG and future growth for serving humanity.

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