

# IUGG in the 21<sup>st</sup> Century

Jo Ann Joselyn<sup>1</sup>, Alik Ismail-Zadeh<sup>2,3</sup>, Tom Beer<sup>4</sup>, Harsh Gupta<sup>5</sup>, Masaru Kono<sup>6</sup>, Uri Shamir<sup>7</sup>, Michael Sideris<sup>8</sup>, and Kathryn Whaler<sup>9</sup>

<sup>1</sup> Retired from the Space Environment Center, National Oceanic and Atmospheric Administration, Boulder, Colorado, USA

<sup>2</sup> Karlsruhe Institute of Technology, Institute of Applied Geophysics, Karlsruhe, Germany

<sup>3</sup> Russian Academy of Sciences, Institute of Earthquake Prediction Theory and Mathematical Geophysics, Moscow, Russia

<sup>4</sup> Safe System Solutions Pty Ltd, Brunswick VIC, 3056, Australia

<sup>5</sup> National Geophysical Research Institute, Hyderabad, India

<sup>6</sup> Retired from the Tokyo Institute of Technology, Tokyo, Japan

<sup>7</sup> Retired from the Israel Institute of Technology, Haifa, Israel

<sup>8</sup> University of Calgary, Schulich School of Engineering, Department of Geomatics Engineering, Calgary, Canada

<sup>9</sup> University of Edinburgh, School of GeoSciences, Edinburgh, Scotland, UK

Correspondence to: Alik Ismail-Zadeh ([alik.ismail-zadeh@kit.edu](mailto:alik.ismail-zadeh@kit.edu)); Jo Ann Joselyn ([jjoselyn@earthlink.net](mailto:jjoselyn@earthlink.net))

**Abstract.** The International Union of Geodesy and Geophysics (IUGG) has vigorously responded to a number of the natural, scientific, and technological challenges and driving forces that have marked the 21<sup>st</sup> century thus far. This paper reviews the actions of the Union that were precipitated by disasters caused by natural hazard events, climatic and environmental changes, and important scientific advances, as well as the opportunities to support International Years and other cooperative programs. This period has also given rise to a number of structural changes within the union. IUGG added an eighth association, the International Association of Cryospheric Sciences, and inaugurated the new categories of affiliate and honorary memberships, introduced new grants, science education, and recognition programs, and formed new Union commissions on climatic and environmental change, data and information, planetary sciences, and a working group on history. Electronic communication was welcomed as a cultural norm. Overall, the development of the scientific landscape in the 21<sup>st</sup> century and a healthy future for the Union requires emphasis on fundamental Earth and space sciences as well as on transdisciplinary science to resolve urgent problems of society. IUGG will continue to evolve throughout the coming decades in step with the changing world of science and its international organizations, by responding to challenging problems as they arise.

## 1 Introduction

This is the last of three papers dedicated to the centennial history of the International Union of Geodesy and Geophysics (IUGG). The first paper (Ismail-Zadeh and Joselyn, 2019; *current Special Issue*) introduces the Union presenting its mission, membership, structure, programs, products, and partners, and then overviews the formation of the Union and its development until the beginning of WWII. The second paper (Joselyn and Ismail-Zadeh, 2019; *current Special Issue*) describes the IUGG's evolution and its activities during the post-WWII era until the end of the 20<sup>th</sup> century.

Founded by nine scientific academies of the allied nations, the number of member countries increased to 35 by 1939 and to 76 by 1999, although some countries joined and left the Union over time. 22 general assemblies (and two extraordinary assemblies) were held in different international venues, and the number of delegates attending the general assemblies increased from a few dozen to more than four thousand scientists. Each general assembly of the Union since the First General Assembly in 1922 until the XXII General Assembly in 1999 has been summarized by Ismail-Zadeh and Joselyn (2019) and Joselyn and Ismail-Zadeh (2019). The International Geophysical Year (IGY; 1957-1958) initiated by IUGG and its national members and co-sponsored by the

41 International Council of Scientific Unions (ICSU; now the International Science Council [ISC]) and the World Meteorological  
42 Organization (WMO) was an extraordinary global scientific effort. It was one of the most successful scientific and outreach  
43 programs of the last century bringing together natural and social scientists, engineers, politicians, media, and society. After the  
44 IGY, international multi- and interdisciplinary scientific campaigns became commonplace; many new international scientific  
45 bodies were formed by ICSU with the IUGG's participation; many geophysical observatories were founded; the Union initiated  
46 and rigorously supported a number of international scientific programs (see Table 1 in Joselyn and Ismail-Zadeh, 2019).

47  
48 This paper starts with a review of the activities of the Union related to fostering research on disaster risks, and climatic and  
49 environmental changes. It discusses the IUGG involvement in and support of International Years and other cooperative programs  
50 during almost two decades of the 21<sup>st</sup> century (at the time of writing). A number of structural changes occurred within the Union,  
51 and the most important of which was establishment of the International Association of Cryospheric Sciences, an eighth association  
52 of the Union, in 2007. IUGG agreed to establish the new categories of affiliate and honorary memberships, introduced new grants,  
53 geoscience education, and recognition programs, and formed new Union commissions on climatic and environmental change, data  
54 and information, planetary sciences, and a working group on history. The development of the scientific landscape in this century  
55 and a healthy future for the Union requires emphasis on fundamental sciences as well as on transdisciplinary science to help in  
56 solving urgent problems of society.

## 57 58     **2 Promoting natural hazards and disaster risk science**

59  
60 The early years of the 21<sup>st</sup> century have been marked by a number of extreme natural events and associated great disasters that  
61 have strongly influenced both public policy and scientific research (e.g., Cutter et al., 2015). These include earthquakes (e.g., 2004  
62 Aceh-Sumatra in the Indian Ocean in 2005, Kashmir (Pakistan) in 2005, Wenchuan (China) in 2008, Haiti in 2010, Tohoku (Japan)  
63 in 2011, and Nepal in 2015) that triggered tsunamis and/or landslides; floods (e.g., in western and central Europe in 2002, China  
64 in 2007; Taiwan and Philippines in 2009); and cyclones and hurricanes (e.g. hurricanes Katrina in 2005 and Harvey in 2017, both  
65 in USA; cyclone Nargis in Myanmar in 2008). These and other extreme events have resulted in tragic losses of life and  
66 infrastructure.

67  
68 Several of the IUGG Associations and inter-Association commissions address potentially violent geophysical processes. In August  
69 2000, IUGG created the Union Commission on Geophysical Risk and Sustainability (GRC) specifically to study the likelihood of  
70 hazards, their impacts and consequences as a result of the vulnerability of societies, and to recommend measures for adaptation and  
71 mitigation. Thus, the commission was ready when a magnitude 9.2 earthquake struck on 26 December 2004 off the west coast of  
72 northern Sumatra, South Asia. The resulting tsunamis inundated the coastal zones around the Indian Ocean and resulted in losses  
73 of more than 230,000 lives across many countries. A few months before the event, the GRC had released the first catalogue of  
74 tsunamis in the Indian Ocean to the public. The GRC, in cooperation with the IUGG inter-association Tsunami Commission,  
75 prepared a statement that was sent to the Secretariat of the United Nations International Strategy for Disaster Reduction (UNISDR)  
76 and presented by the IUGG Vice President Tom Beer to the United Nations World Conference on Disaster Reduction in Kobe,  
77 Japan (January 2005). This statement was revised and adopted as IUGG Resolution 8 "Reduction of Risk from Natural Hazards" at  
78 the General Assembly in Perugia, Italy in 2007 (IUGG Archives, 2007). Several IUGG Associations responded by convening  
79 workshops and symposia to study the relevant geophysical process and presented recommendations for observation, analysis and  
80 warning systems. On 12 January 2010, a strong earthquake of magnitude 7 struck Port-au-Prince, Haiti, and resulted in a death toll

81 that was estimated to range from 100,000 to 316,000. After the earthquake, on 29 January 2010, IUGG issued a special resolution:  
82 “Science on Natural Hazards and Environmental Disasters”, urging the “international science community to quantify natural hazards  
83 and extreme events at all scales; to adopt integrative and comprehensive interdisciplinary approaches towards developing adaptation  
84 in order to decrease vulnerability; and to produce planning tools for disaster risk reduction at all scales.” This and all other IUGG  
85 statements can be found on the IUGG website under Special Resolutions and Statements (<http://www.iugg.org/about/special.php>).  
86

87 A political consequence of scientific efforts to understand and predict natural disasters and inform society occurred in 2009 when  
88 the L'Aquila (Italy) Prosecutor's office indicted the members of the Abruzzi region's High Risk Committee for unintended murder  
89 for issuing statements to calm the population before the strong earthquake of 6 April that killed about 300 people. Believing that  
90 no scientist should be prosecuted for having expressed a scientific opinion based on the available knowledge that is often  
91 necessarily limited, IUGG issued in June 2010 a statement on “Freedom to Conduct Science and Responsibilities of Scientists”  
92 highlighting the ICSU Principle of the Universality of Science. This principle encompasses freedom in relation to expressions of  
93 scientific ideas, hypotheses and forecasts, to conduct research using data, information, experiments and theories, and to  
94 communicate scientific results to the public through open publications and scientific conferences. Italy's Supreme Court finally  
95 cleared the committee's members in 2015, after a judicial process lasting more than 5 years (Cartlidge, 2015).  
96

97 IUGG released two statements related to the eruptions of the Eyjafjallajökull volcano in Iceland that highlighted the importance of  
98 understanding the eruptive state of each of the world's active volcanoes for the safety and health of local residents as well as for  
99 air traffic and global climate. The first statement on Volcanic Ash Clouds (20 April 2010) was distributed at the Congressional  
100 Briefings on Reducing Volcano Risks in the U.S. Senate and the House of Representatives. The second statement on  
101 Volcanological and Meteorological Support for Volcanic Ash Monitoring (28 May 2010) was welcomed by the WMO Executive  
102 Board and the International Civil Aviation Organization (ICAO). Both statements can be found on the IUGG website, as specified  
103 above.

104  
105 On 11 March 2011 a magnitude 9.0 earthquake occurred off the Pacific Coast of Tohoku, Japan. It induced a catastrophic tsunami  
106 that hit the coasts of Tohoku and Kanto. The toll of dead and missing exceeded 18,000 people and critically damaged a Japanese  
107 nuclear power plant. IUGG expressed heartfelt sympathy for the victims, and again the GRC prepared a statement on the Great  
108 East Japan Earthquake and Tsunami that was adopted by the IUGG Bureau.  
109

110 With the aim of strengthening international cooperation in disaster risk science, IUGG accepted a proposal by Secretary General  
111 Alik Ismail-Zadeh and initiated in 2010 an interdisciplinary international project entitled “Extreme Natural Hazards and Societal  
112 Implications – ENHANS” (<http://www.icsu-geounions.org/enhans>), then co-sponsored by ICSU and several international and  
113 intergovernmental organizations. The major scientific results of the project were published in the IUGG volume *Extreme Natural  
114 Hazards, Disaster Risks and Societal Implications* (Ismail-Zadeh et al., 2014). The ENHANS project concluded that a reduction  
115 of disaster risk could be reached through in-depth scientific research on the topic and through disaster risk assessments.  
116

117 In 2011, IUGG President Harsh Gupta and Secretary General Alik Ismail-Zadeh submitted a resolution on disaster risk assessment  
118 to the 30th ICSU General Assembly. The ICSU Executive Board then opened global discussions on the need for an  
119 intergovernmental body for the assessment of disaster risk and directed the preparation of a multi-disciplinary report that was  
120 presented at the 31st ICSU General Assembly (2014). The assembly applauded the initiatives on disaster risk assessment

undertaken by the Integrated Research on Disaster Risk (IRDR) program, ICSU, the International Social Science Council (ISSC), and the UNISDR, as well as the international scientific unions and the Council's Regional Offices, and invited individual national members to support the proposed intergovernmental disaster risk assessment process. After the ICSU General Assembly, ICSU and ISSC formed a joint ad-hoc group of experts, co-chaired by ICSU President Gordon McBean and IUGG Secretary General Alik Ismail-Zadeh, to prepare a synthesis report on disaster risk research and risk assessment to be presented at the United Nations Third Conference on Disaster Risk Reduction held in Sendai, Japan, in 2015 (Ismail-Zadeh and Cutter, 2015). The report was published before the conference, and its executive summary was distributed among the delegates of the conference at the request of the Russian Federation.

### 3 Promoting climatic and environmental science

Among the environmental problems IUGG addresses are climate, its variability and the contribution of CO<sub>2</sub> emission to its change in order to save our planet for future generations; environmental pollution and its reduction in megacities to improve the quality of life; weather and water conditions to assist farmers during harvests and provide other indispensable ecosystem services; clean water and decontamination of polluted water to preserve and enhance human and ecosystem health; pollution of oceans and seas, biodiversity and food security. Representing many disciplines of Earth and space sciences, IUGG has been continuously involved in projects and programs related to climatic and environmental changes and their impacts.

By the middle of the 20<sup>th</sup> century, the impacts of climatic and environmental changes were well understood by many experts involved in relevant studies and programs of ICSU or other international bodies (Weart, 2012). The experts proposed that a major scientific program on climate be established, and after long debates, the World Climate Research Programme (WCRP) was set up by WMO and ICSU in 1980 (later the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization [UNESCO] joined ICSU and WMO as a co-sponsor) in order to "determine the predictability of climate and to determine the effect of human activities on climate" (from the WCRP mission statement). IUGG experts contributed to the process of setting up the Intergovernmental Panel on Climate Change (IPCC) to help raise awareness of societies and politicians about climate change (Bolin, 2007). Among them was Bert Bolin (IUGG Bureau Member, 1963-1967), who was involved in setting up and development of the Global Atmospheric Research Programme (Ashford, 1982) as well as WCRP, the International Geosphere-Biosphere Programme, and IPCC, becoming its first Chairman (Rohde, 2013). Many IUGG experts shared the 2007 Nobel Peace Prize with the IPCC and Al Gore (Ismail-Zadeh, 2016).

In 2012, IUGG established the Union Commission on Climatic and Environmental Change (CCEC) to promote the advancement of scientific understanding of climatic and environmental change, to boost research in reducing uncertainties in climate and environmental models, to define criteria for collaborative transdisciplinary research on climate and environmental change, to fulfill the objectives of IUGG and its Associations, to provide an all-Union perspective on climatic and environmental change, and to make available the knowledge and insights developed through scientific research for the benefit of society and planet Earth, including consideration of the science of global change, related vulnerability and impacts, and potential responses. CCEC provides a focus for IUGG scientific expertise in climate and environment related areas across the breadth of all IUGG disciplines. CCEC enables the breadth of IUGG expertise to be brought to bear at the global level through collaborating with, and underpinning the work of ICSU and other international organizations. It also enables the geographic spread of IUGG expertise to be brought to bear at the local level through involvement with national bodies in the organization of scientific meetings and other activities. The

161 research on the climatic and environmental change and high-impact of weather and climate events by the members of the CCEC  
162 and the Climate Commission of the International Association of Meteorology and Atmospheric Sciences (IAMAS) of IUGG was  
163 published as an IUGG volume by Cambridge University Press (Li et al., 2016). The work of CCEC demonstrated how multi- and  
164 interdisciplinary research outputs from the geoscience community can be applied to tackle the physical and societal impacts of  
165 climate change and to contribute to Future Earth, a major environmental program initiated by the International Science Council  
166 (Beer et al., 2018).

167

168 At the request of the IUGG Secretary General Alik Ismail-Zadeh, fourteen international experts of the International Association  
169 on the Physical Sciences of the Oceans (IAPSO) of IUGG together with those of the ICSU Scientific Committee on Oceanic  
170 Research (SCOR) developed a synthesis report *Future of the Ocean and its Seas* (Williamson et al., 2016) for science policymakers  
171 of seven economically developed countries (G7 Science Ministers). The report was prepared for the annual meeting of G7 Science  
172 Ministers held in Tsukuba, Japan, in May 2016, as a response of non-governmental scientific organizations to the concern of the  
173 policymakers expressed at their meeting in Berlin, Germany, in September 2015. The experts addressed topics related to plastic  
174 pollution of the marine environment, deep-sea mining and its ecosystem impacts, ocean acidification, deoxygenation, ocean  
175 warming, biodiversity loss, and marine ecosystem degradation.

#### 176

#### 177 **4 International Years**

178

179 The United Nations is the body that declares “International Years” (IY). The process requires both non-governmental and  
180 governmental support at the highest levels. To mark fifty years after the remarkable International Geophysical Year (1957-58),  
181 three related IYs to conduct scientific programs were successfully proposed. These were the International Year of Planet Earth  
182 (IYPE), the International Polar Year (IPY), and the International Heliophysical Year (IHY). A fourth international program, the  
183 electronic Geophysical Year (eGY), joined the others to support this scientific focus. IUGG and the Union Associations were  
184 active in developing these programs and provided leadership and support for each. The four programs met in 2008 and issued the  
185 Tsukuba Declaration (<http://www.egy.org>), noting that scientific cooperation among the global science community, national  
186 academies of sciences, research funding agencies, industry, national governments, and inter-governmental bodies provide society  
187 and its leaders with the best possible information to make decisions on a sustainable future for humankind. Table 1 lists the  
188 International Years initiated and/or supported by IUGG since 2001.

#### 189

#### 190 **5 GeoUnions**

191

192 In 2004, representatives of several ICSU International Scientific Unions dealing with Earth and space sciences met in Paris to  
193 establish a partnership to better promote the geosciences worldwide, to communicate and to coordinate scientific activities of  
194 individual unions, and to gain recognition by ICSU bodies, the United Nations organizations, and other global stakeholders. The  
195 partnership has endured as the GeoUnions. Current members are the International Astronomical Union, the International  
196 Cartographic Association, the International Geographical Union, the International Union for Quaternary Research, the International  
197 Society for Photogrammetry and Remote Sensing, IUGG, the International Union of Geological Sciences, the International Union  
198 of Soil Sciences, and the International Union of Radio Science.

200 The GeoUnions Steering Committee has developed a website (<http://icsu-geounions.org>) to inform the scientific community about  
201 joint activities. The GeoUnions network has persisted and has proved powerful in fostering integrated interdisciplinary research.  
202 An example of one such collaboration is the Geoscience in Africa initiative, launched in 2003 by then IUGG President Uri Shamir,  
203 based on the recognition that geophysical processes are global and that African scientists suffer, more than others in the rest of the  
204 world, from shortage of resources, shortage of an adequate cadre of trained scientists, and lack of government recognition and  
205 support. Adopted as a science program of the GeoUnions, this effort supported the ICSU Regional Office in Africa, and  
206 “eGYAfrica - better Internet connectivity for research and education institutions in Africa”, and the ENHANS project noted above.  
207 Current key areas are disaster risk reduction and the International Year of Global Understanding (IYGU).

208

## 209     **6       IUGG structure**

210

211 A significant change to the IUGG structure in the 21<sup>st</sup> Century was the addition of an eighth Association, the International  
212 Association of Cryospheric Sciences. The new Association had its origins with the IAHS International Commission on Snow and  
213 Ice (ICSI), formally established in 1948 but with roots extending back to 1894. At the 2004 IUGG Executive Committee meeting,  
214 a Union Commission for the Cryospheric Sciences (IUGG/CCS) was proposed by IAHS and supported by IAMAS, IAPSO, and  
215 IAVCEI. The Commission began work on its proposed Association statutes and by-laws, organized international symposia and  
216 planned scientific sessions for the 2007 IUGG General Assembly. In the meantime, changes in the IUGG statutes and by-laws and  
217 other administrative and financial procedures were prepared to make way for a new Association. By action of the IUGG Council  
218 on 4 July 2007, the new Association was welcomed into the IUGG family.

219

220 After the General Assembly in Birmingham, UK (1999), election procedures for IUGG officers were modified to allow additional  
221 nominations following the report of the Nominating Committee. At the General Assembly in Perugia, Italy (2007), the duties of  
222 the Bureau, the Secretary General and the Treasurer with regard to the administration were refined, and statute 27 was modified  
223 so that while French and English are the official languages of the Union, the English version of the statutes is now the definitive  
224 version of the text. The membership and duties of the Finance Committee were addressed at the 2003 and 2011 General Assemblies,  
225 and at the General Assembly in Melbourne, Australia (2011), IUGG Honorary membership (Fellows) was instituted to honor  
226 individuals for their exceptional contribution to Earth and space sciences or international cooperation in geodesy or geophysics.

227

228 At the General Assembly in Prague, Czech Republic (2015), the composition of National Committees was clarified in order to  
229 advance the participatory culture of the Union and improve transparency. Also in Prague, it was decided that delegates to the IUGG  
230 Council should be appointed by the Adhering Bodies of Member Countries for the period between General Assemblies (normally  
231 for four years) so that the Council could vote electronically and make decisions between General Assemblies. This provision  
232 permitted the IUGG Bureau to propose several changes to the statutes and by-laws following the Prague General Assembly. After  
233 consultations with the IUGG Council, the changes were approved unanimously on 5 April 2018 by electronic ballot. The position  
234 of Vice President was replaced by President-elect, who then becomes President of the Union in the following term of office. The  
235 number of members of the Finance Committee was reduced from four to three people and the terms of office of the Secretary  
236 General, Treasurer, Bureau Members at large and Finance Committee members were redefined. The vote of the immediate Past  
237 President at the Executive Committee was restored.

238

## 239     **7       IUGG membership and finance**

240  
241 The IUGG Council has approved a number of changes regarding membership since 1999. At the General Assembly in Birmingham,  
242 UK in 1999, the category of Associate Membership (characterized by exemption from paying annual dues) was created; Associate  
243 members were not allowed to sit in Council meetings (as opposed to members in Observer status, who could attend Council  
244 meetings but without vote). A By-Law change clarified that scientists from all countries could attend scientific meetings of the  
245 Union and of the Associations and participate as observers in Commissions of the Union and in the Associations. At the General  
246 Assembly in Sapporo, Japan (2003), it was decided that one delegate from each Associate member country could attend Council  
247 meetings as listeners only. It was also agreed that other “Listeners” could attend Council meetings with the permission of the  
248 President, although a vote of Council members could exclude Listeners if appropriate. At the General Assembly in Perugia, Italy  
249 (2007), the number of financial categories to determine membership dues was increased to fourteen. At the General Assembly in  
250 Melbourne, Australia (2011), Affiliate membership was added to provide a mechanism to formalize linkages with various  
251 international and regional organizations dealing with Earth and space sciences, and the statutes and by-laws were clarified with  
252 regard to Associate and Observer membership status. At the General Assembly in Prague, Czech Republic (2015), a change was  
253 made to allow a representative of an Associate Member to speak (without the right to vote) at Council meetings, and individuals  
254 from countries in Associate or Observer status or from non-Member countries could be elected to Association office (except for  
255 the position of the Association President because the Association President is a member of the IUGG Executive Committee).  
256

257 As of 1 January 2019, IUGG had 72 National Members (see Appendix 1 for the IUGG Members since 1919, and Table 2 for the  
258 changes in the number of members for the last twenty years). The paying members are placed in categories from 1 to 14 depending  
259 on their financial contribution to the Union (the membership dues rise with increasing category number). At present, the highest  
260 category used is category 11. The members pay dues according to a number of units assigned to their category (in category 1 the  
261 number of units is 1, and in category 11 the number is 35). According to a decision made at the XXII IUGG General Assembly in  
262 Boulder, USA (1995), the price of 1 unit is determined every year using an inflator index obtained from the Bureau of Labor  
263 Statistics, U.S. Department of Labor. The funds received as dues are the basis for the IUGG’s operations as a scientific union,  
264 although Union Associations may have their own funds earned through donations, book sales, or other fundraising efforts. The  
265 funds are spent to support scientific activities of Union Associations and Commissions; international scientific programs, projects  
266 and services; general and scientific assemblies and other meetings; the IUGG Grants and Geoscience Education programs; the  
267 International Lithosphere Program; the International Science Council; travel of students, early career scientists, and scientists from  
268 developing countries to attend scientific meetings; and administration and management.  
269

270 **8 The IUGG Secretariat**

271  
272 The IUGG Secretariat has undergone significant changes to allow for modern governance, especially making use of the World  
273 Wide Web and digital technologies. The Union has had a web site since 1999 maintained by a web-master located in France (1999-  
274 2000, 2005-2007), USA (2000-2005), and Russia (since 2007), and overseen by the IUGG Secretary General. The IUGG Yearbook  
275 was first published electronically in 2004. Annual reports since 2001 (and earlier as digital scans become available) are also posted  
276 online. Since November 2014, the Secretariat has used web-conferencing software to support real-time communications between  
277 IUGG Bureau and Executive Committee Members through text-based instant messages, voice and video chat, online presentations,  
278 web conferences, and desktop sharing. This technology increases communication and productivity, conserves time and reduces

279 travel expenses, and accelerates the decision-making process. IUGG is on Twitter ([twitter.com/theiugg](https://twitter.com/theiugg)) and Facebook  
280 (<https://www.facebook.com/InternationalUnionGeodesyGeophysics>).

281  
282 The IUGG Electronic Journal began monthly publication on 1 February 2001, as a means to communicate the actions of the Union  
283 and the Associations. A web-based IUGG Central Electronic Library (CEL) was established (2013) for stimulating the exchange  
284 of scientific knowledge through (i) archiving, (ii) presenting, and (iii) publishing IUGG-related documents; at present one single  
285 platform for all of this is under construction. IUGG-related documents include reports, yearbooks, e-journals, newsletters,  
286 conference abstracts, oral/poster presentations, and more, originating from the IUGG and its Union Associations, Union  
287 Commissions, Committees, Liaisons, Research Programs, and Science Education Events. New digital IUGG-Association logos  
288 were professionally designed and approved by the Executive Committee in December 2016.

289  
290 From mid-1999 to 2007 the office of the IUGG Secretary General was hosted by the University of Colorado at Boulder, USA,  
291 within the Cooperative Institute for Research in Environmental Sciences (CIRES). The IUGG Secretariat moved to Karlsruhe,  
292 Germany in 2007, where it was hosted by the Geophysical Institute at the Karlsruhe Institute of Technology (KIT; former Karlsruhe  
293 University). On 7 June 2013, at the invitation of Prof. Dr. Reinhard Hüttl, Scientific Executive Director of the GFZ German  
294 Research Centre for Geosciences (GFZ-Potsdam), the office of the IUGG Secretariat was relocated to Potsdam, Germany. Salary  
295 and facilities for an Executive Secretary (Assistant Secretary General) to support the Secretariat are provided by the GFZ-Potsdam.  
296 Additional financial support to the Secretariat comes from the German Research Foundation (DFG), which provides funds for the  
297 position of Assistant of the Executive Secretary and for business travel of the IUGG Secretary General.

298  
299 The IUGG historical records were transferred in 2001 to the Niels Bohr Library of the Center for the History of Physics of the  
300 American Institute of Physics. The historical records consist of documents and correspondence dating from the origin of the Union  
301 in 1919, and extending into the mid-1990's; additional material was sent in December 2007 (AIP, 2019).

## 303     9       **Highlights of IUGG General Assemblies**

304  
305 As the 21<sup>st</sup> century began, the actions from the XXII General Assembly held in Birmingham, UK in 1999 were in place. There was  
306 one change in the officers of the Bureau elected in Birmingham: L. Vere Shannon (South Africa) resigned, and by action of the  
307 Executive Committee, was replaced by Tom Beer (Australia).

### 308     9.1      **XXIII General Assembly (30 June – 11 July 2003, Sapporo, Japan)**

309  
310  
311 IUGG President Masaru Kono (Japan) presided. Vice President was Uri Shamir (Israel), Secretary General was Jo Ann Joselyn  
312 (USA), Treasurer was Aksel W. Hansen (Denmark), and Bureau members were Junyoung Chen (China), Harsh Gupta (India), and  
313 Tom Beer (Australia). This was the first IUGG General Assembly to be held in Asia. His Majesty The Emperor of Japan addressed  
314 the Opening Ceremony (Fig. 1). Seiya Uyeda chaired the Local Organizing Committee, and Atsuhiro Nishida chaired the Scientific  
315 Programme Committee. The theme of the General Assembly was "State of the Planet: Frontiers and Challenges", and featured four  
316 Union lectures and 182 scientific sessions including eight Union Symposia. The IUGG volume "The State of the Planet: Frontiers  
317 and Challenges in Geophysics" was published in the AGU Geophysical Monograph series (Sparks and Hawkesworth, 2004).

318 Attendance was impacted by a serious global outbreak of the Sudden Acute Respiratory Syndrome (SARS); some had to delay or  
319 cancel travel arrangements due to precautionary requirements.

320  
321 Three special committees presented reports: IUGG Structure, Goals, and Objectives; IGY+50, which began as a simple celebration  
322 but culminated in four major international programs as described earlier: eGY, IHY, IPY, and IYPE. A special Union Symposium  
323 "Geosciences – The Future" was presented by a working group of young scientists that was initiated by Vice President Uri Shamir,  
324 to stimulate involvement and leadership by early career scientists. A discussion of IUGG Structures, Goals, and Objectives centered  
325 on the responses to questionnaires that had been submitted to the IUGG Adhering bodies, National Committees, and Associations.  
326 An addition to Council business was an informal meeting of the delegates led by R. Stewart (Canada) during which delegates could  
327 freely express ideas and opinions.

328  
329 During this quadrennium, IUGG allocated financial support for meeting attendance and inter-Association initiatives to benefit  
330 developing countries (22 meetings, workshops and schools in 17 different countries), as well as interdisciplinary and inter-Union  
331 initiatives that particularly benefited developing countries. ICSU also awarded grants to promote Association research objectives.

332  
333 Resolutions (IUGG Archives, 2003) were adopted that supported geophysical seafloor observations, ocean modeling, a geodetic  
334 observing system, Earth monitoring with synthetic aperture radar, data access under the Comprehensive Nuclear-Test-Ban Treaty  
335 (CTBT), and the need for release of airborne and marine magnetic data.

336  
337 **9.2 XXIV General Assembly (2-13 July 2007, Perugia, Italy)**

338  
339 IUGG President Uri Shamir (Israel) presided. Vice President was Tom Beer (Australia), Jo Ann Joselyn (USA) continued as  
340 Secretary General, Aksel W. Hansen (Denmark) as Treasurer, and Bureau members were Yun-tai Chen (China), Harsh Gupta  
341 (India), and Ali A.A. Tealeb (Egypt). Held in the historic Umbria Region of Italy, Lucio Ubertini chaired the Local Organizing  
342 Committee and Paola Malanotte-Rizzoli chaired the Scientific Program Committee. The theme was "Earth: Our Changing Planet",  
343 and the assembly featured four Union lectures, thirteen Union symposia, and 187 Association and inter-Association symposia and  
344 workshops.

345  
346 The International Association for Cryospheric Sciences (IACS) became the 8<sup>th</sup> IUGG Association (Fig. 2). A new document,  
347 Guidelines on IUGG Administration, was introduced. The 50th Anniversary of the IGY was celebrated, and the eGY was  
348 inaugurated, joining the other IGY+50 scientific programs: IHY, IPY, and IYPE.

349  
350 During the preceding four years, IUGG allocated funds to the organizers of 32 symposia, workshops, schools or meetings in 25  
351 different countries, most of them developing countries. In addition, grants were allocated in the years 2004 and 2005 to support  
352 eight inter-Association initiatives that specifically benefited developing countries. By action of the 2005 Executive Committee, the  
353 grants were suspended for 2006-2007 in order to build a reserve that could be used to seed potential initiatives under Geosciences  
354 in Africa. This program, adopted by the GeoUnions, cooperated with the ICSU Regional Office in Africa and supported the eGY-  
355 Africa program to help to reduce the digital divide through better Internet access for scientists (and others) in Universities and  
356 similar institutions in Africa. In addition, IUGG supported inter-Union activities, including ILP, WCRP, and the Federation of  
357 Astronomical and Geophysical Data Analysis Services (FAGS). IUGG received competitive grants from ICSU to promote IAGA

358 and IAHS research objectives; nominated persons for numerous panels and working groups, and endorsed the ICSU “Agenda for  
359 Action” with regard to Science in the Information Society.

360  
361 Resolutions (IUGG Archives, 2007) adopted included support of an International Astronomical Union’s resolution on  
362 nomenclature and definition of TDB (Temps Dynamique Barycentrique); support of Geocentric and International Terrestrial  
363 Reference Systems (GTRS and ITRS) and the Global Geodetic Observing System (GGOS); eGY and Data Rescue; Ionosphere  
364 Satellites; The Urgency of Addressing Climate Change; Intensified Study of Aerosol Pollution Effects on Precipitation; and  
365 Reduction of Risk from Natural Hazards.

366

367 **9.3 XXV General Assembly (27 June - 8 July 2011 - Melbourne, Australia)**

368  
369 IUGG President Tom Beer (Australia) presided. Vice President was Harsh Gupta (India), Secretary General was Alik Ismail-Zadeh  
370 (Germany/Russia), Aksel W. Hansen (Denmark) continued as Treasurer, and Bureau members were Yun-tai Chen (China), David  
371 Jackson (USA) and Ali A.A. Tealeb (Egypt). This was the second IUGG General Assembly to be held in Australia, and the third  
372 time it was held outside of Europe and North America. Ray Cas chaired the Joint Australia and New Zealand Organizing Committee  
373 and Peter Manins coordinated the Scientific Program Committee. The theme was “Earth on the Edge: Science for a Sustainable  
374 Planet”, and the assembly featured nine Union lectures and a total of 198 symposia and workshops.

375  
376 The Royal Society (the UK Adhering Body to IUGG) developed a program to engage African scientists in the work of ICSU  
377 international unions, and paid for three years membership dues of the Democratic Republic of Congo, Ghana, and Morocco, IUGG  
378 Associate Members, allowing them to participate in full in Union’s activities. IUGG co-sponsored and took an active part in the  
379 international programs dedicated to the 50th anniversary of the IGY. Association scientific assemblies were held in Reykjavík,  
380 Iceland (IAVCEI); in Cape Town, South Africa (IASPEI); MOCA, a joint assembly of IAMAS, IAPSO and IACS was held in  
381 Montreal, Canada; IAGA held its assembly in Sopron, Hungary; IAG met in Buenos Aires, Argentina; and IAHS held its assembly  
382 together with the International Association of Hydrogeologists in Hyderabad (India). The IUGG Union Commissions organized  
383 several conferences and symposia: two CMG conferences on mathematical geophysics in Longyearbyen (Norway), and in Pisa  
384 (Italy), two SEDI conferences in Kunming (China), and Berkeley (USA), and three GRC symposia in Barcelona (Spain), Oslo  
385 (Norway), and Torino (Italy). GRC took active part in the organization and running of the ICSU-sponsored ENHANS project  
386 events in Iguassu (Brazil), San Francisco (USA), Pretoria (South Africa), Antalya (Turkey), and Melbourne (Australia). A new  
387 Union Commission for Data and Information was set up to provide a focused and sustainable organizational structure that supports  
388 and strengthens IUGG science through integrated scientific information activities. Four new Union Committees on Capacity  
389 Building and Education, Honours and Recognition, Membership Issues, and Visioning were set up to increase IUGG visibility  
390 worldwide.

391  
392 Seven multi- and interdisciplinary international scientific projects were supported through the IUGG Grants Program. IUGG  
393 meeting support was allocated to the organizers of 43 symposia, workshops, schools or meetings in 31 different countries, most of  
394 them in developing countries. ICSU competitive grants were awarded to promote research on natural hazards and disaster risks as  
395 well as geophysical research and geoinformation in Africa. IUGG also supported inter-Union activities, including ILP, the WCRP,  
396 and FAGS, now transformed into the World Data System (WDS).

398 Resolutions (IUGG Archives, 2011) that were adopted included the issue of standardizing terminology for glacier mass balance  
399 measurements and for classification of snow on the ground; endorsement of the International Celestial Reference Frame; the need  
400 for gravity and magnetic field satellite missions; and adoption of the International Thermodynamic Equation of Seawater – 2010  
401 (TEOS-10). It was noted that the IUGG Executive Committee had adopted several resolutions and statements during the inter-  
402 General Assemblies period with regard to several natural disasters (noted elsewhere).

403

404 **9.4 XXVI General Assembly (22 June - 2 July 2015, Prague, Czech Republic)**

405

406 IUGG President Harsh Gupta (India) presided. Vice President was Michael Sideris (Canada), Secretary General was Alik Ismail-  
407 Zadeh (Germany/Russia), Aksel W. Hansen (Denmark) was Treasurer, and Bureau members were Isabelle Ansorge (South Africa),  
408 Pierre Hubert (France), and Kenji Satake (Japan). Prague was the only city to host the IUGG assembly for the second time, having  
409 hosted the Third IUGG General Assembly in 1927. Vladimir Cermak chaired the Local Organizing Committee and Eduard  
410 Petrovsky chaired the Scientific Program Committee. The Theme of the General Assembly was “Earth and Environmental Sciences  
411 for Future Generations”. There were nine Union lectures and 11 Union symposia; Nobel Prize winner Y.T. Lee presented a Union  
412 lecture on “Transformation of human society for sustainable future.” The scientific program included 198 symposia and workshops.

413

414 The Visioning Committee prepared, and the delegates approved, a draft Strategic Plan for 2016-2023 to be developed along with  
415 a plan for implementation (the final plan was approved by the Council by electronic ballot in 2016; the implementation actions  
416 were approved by the Bureau in 2017). A new category of Union Membership, Affiliate, was established to strengthen cooperation  
417 with geoscientific organizations worldwide. Since 2012, six scientific organizations became IUGG Affiliate Members: the  
418 Commission for the Geological Map of the World, the Young Earth Scientists Network, the American Geosciences Institute, the  
419 International Association for Mathematical Geosciences, the International Landslides Consortium, and the International  
420 Association for Geoethics.

421

422 The first IUGG awards were presented (Fig. 3). The full list of IUGG Early Career Scientist Awards, Elected Fellows who have  
423 made outstanding contributions to geodesy and geophysics, and Conferred Fellows honored for service as officers of IUGG and  
424 the Associations, is maintained on the IUGG website. The IUGG Gold Medal was awarded to Sir Brian J. Hoskins (UK) for “his  
425 scientific contributions that have been pioneering and profound in almost all aspects of the atmospheric and climatological sciences,  
426 with strong linkages to IUGG and its Associations.”

427

428 An agreement was signed with Cambridge University Press to develop a new series of special publications of the IUGG to publish  
429 peer-reviewed books on perspectives and reviews in multidisciplinary research. The first volume of this series, “*Extreme Natural  
430 Hazards, Disaster Risks and Societal Implications*” was published in 2014 (Ismail-Zadeh et al., 2014), the second volume  
431 “*Dynamics and Predictability of Large-Scale, High-Impact Weather and Climate Events*” in 2016 (Li et al., 2016), and the third  
432 volume “*Global Change and Future Earth*” in 2018 (Beer et al., 2018). IUGG established a new Science Education Program to  
433 enhance geophysical and geodetic science education. In 2012-2015, IUGG funded 24 advanced schools and workshops at the  
434 Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy. ICSU grants promoted geophysical research in  
435 Africa and funds to network the magnetic community in the northern Indian Ocean region. Also, nine interdisciplinary international  
436 scientific projects were supported through the IUGG Grants Program.

437

438 In 2013 IAVCEI proposed to open membership of IUGG to individual scientists at the same time as the IUGG Executive  
439 Committee was discussing various possibilities for individual Union membership. Based on the majority of the opinions from  
440 Union Associations and National Members, the IUGG Executive Committee agreed that the Union should continue with National,  
441 Affiliate, and Honorary Memberships, and each Union Association may introduce individual membership programs to allow active  
442 scientists from non-Member countries to participate in activities of Associations. Association scientific assemblies were held on  
443 several continents in 2013: the joint Scientific Assembly DACA-13 of cryospheric (IACS) and atmospheric (IAMAS) scientists in  
444 Davos, Switzerland; the IAGA Scientific Assembly in Merida, Mexico; the joint Scientific Assembly of hydrologists (IAHS),  
445 oceanographers (IAPSO) and seismologists (IASPEI) “Knowledge for the Future” in Gothenburg, Sweden; the IAVCEI Scientific  
446 Assembly in Kagoshima, Japan; and the IAG Scientific Assembly in Potsdam (Germany) celebrating the 150th anniversary of the  
447 association. The IUGG Union Commissions organized seven scientific events in Asia, Europe, and North America. The Union co-  
448 sponsored 43 international scientific events.

449

450 Resolutions (IUGG Archives, 2015) that were adopted included the Role of Ocean in Climate, Future Satellite Gravity and  
451 Magnetic Mission Constellations, the Global Geodetic Reference Frame, Real-time GNSS (Global Navigation Satellite System)  
452 Augmentation of the Tsunami Early Warning System, and cooperation in Geo-energy Resources and International Scientific  
453 Activities.

454

455 The members of the Bureau for the ensuing quadrennial were elected: President Michael Sideris (Canada); Vice President Kathryn  
456 Whaler (U.K.); Secretary General Alik Ismail-Zadeh (Russia/Germany); Treasurer Aksel W. Hansen (Denmark); Bureau  
457 Members: Isabelle Ansorge (South Africa), Pierre Hubert (France) and Chris Rizos (Australia). A vote of the delegates selected  
458 Montreal, Canada as the venue of the XXVII IUGG General Assembly (8-18 July 2019).

459

## 460 10 IUGG Tomorrow

461

462 IUGG is entering its second century. A healthy future for the Union requires emphasis on basic Earth and space sciences as well  
463 as science for society. The landscape of Earth and space sciences is changing: we are witnesses of pressing challenges, such as  
464 sprawling towns and the growth of megacities, climatic and environmental change; ocean acidification and sea pollution; disasters  
465 due to natural and human-induced hazards and associated losses due to vulnerability of societies; unsustainable land use; food  
466 insecurity; and depletion and scarcity of mineral resources and water. The importance of scientific understanding of the urgent  
467 problems of society has never been greater, as humanity engages in the problems of living sustainably on planet Earth.  
468 Governments, funding agencies, international and national organizations, professional societies and international unions are  
469 dedicating more attention to the aspects of research related to the environment, renewable natural resources, clean water, disaster  
470 reduction, resilience and others. To address these challenges, the scientific community decided in 2017 to form a new council, the  
471 International Science Council (ISC), merging ICSU and ISSC, to create a unified, global voice of science with a powerful presence  
472 in all regions of the world and representation across the natural and social sciences. As a founding member of ISC, the Union has  
473 a responsibility to ensure that its activities align with the ISC’s agenda.

474

### 475 10.1 Basic research

476

477 Geoscientists need to continue to put their basic results to use, and inter- and trans-disciplinary (ITD) approaches are vital to  
478 making progress in science for society. The coupling between the spheres of the Earth and space sciences as well as between those  
479 and social sciences is often lost. Integrated research combining expertise from relevant disciplines will help quantify the observed  
480 processes and, more importantly, elucidate which interactions between spheres are essential. According to Adams (2013), the best  
481 science results from international collaboration, and hence IUGG should think about new ways and incentives to enable more  
482 scientists to participate in international networks. This need for increased collaboration is set against changes in the current science  
483 landscape and sociopolitical environment that make international cooperation more difficult. Given these realities, IUGG will have  
484 to work especially diligently to adapt to this new environment and promote cooperation.

485

## 486 **10.2 Data issues**

487

488 The Internet and advances in technology have been enhancing the ability of scientists to collect, archive, and distribute data across  
489 all fields and nations. Strengthening norms around openly accessible research and broadening global access to data, digital  
490 technologies, and reliable internet connections would be a boon to scientists in developing countries and to  
491 independent/unaffiliated scholars everywhere, enabling them to further advance their own research thanks to prompt and equal  
492 access to advanced datasets and model results. In order to make the promises of the digital age a reality, existing geodetic and  
493 geophysical data centers and data services should be expanded, and new multi-disciplinary data centers and data services should  
494 be established to enable scientists to work in interdisciplinary areas with unrestricted access to data for scientific research. Also,  
495 such centers could make data produced with public participation (sometimes called “citizen science” data) more valuable, e.g. ash  
496 samples collected after the 2010 eruptions of Eyjafjallajökull in Iceland or felt earthquake information.

497

498 A significant challenge facing geosciences is to combine “big data” (that is, the large volume, high velocity and/or variety data  
499 assets that demand modern forms of processing enabling deep insight and decision making) with state-of-the-art models for better  
500 understanding of nature’s complex systems. This will be a key component of progress in geosciences in the near future. IUGG, via  
501 its permanent geodetic and geophysical services, should continue to promote the development of existing and new sophisticated,  
502 cutting-edge methodologies and tools in data collection, transmission, analysis, and dissemination of outputs to help address  
503 challenging problems in Earth and space sciences. The IUGG’s role in promoting an open data policy as well as the activities of  
504 observational and data services and in encouraging international investment in observing systems is, and will continue to be,  
505 important. We envisage that IUGG will enhance its working relationship with such bodies as the intergovernmental Group on  
506 Earth Observations (GEO), CODATA and WDS to promote data curation and openness and data analysis for new discoveries.  
507 Knowledge transfer can be accomplished successfully by utilizing mass media outlets as well as by traditional ways of cooperation  
508 with policymakers. The web and social media are the best ways to reach the youth audience, a key demographic in ensuring the  
509 future of geoscientific research, as well as a broader audience more generally, including communities that may not have had much  
510 access to advanced scientific findings in the past (e.g., communities lacking financial or scholarly resources).

511

## 512 **10.3 Interdisciplinarity**

513

514 Societal problems need an integrated, trans-disciplinary scientific approach (e.g., Ismail-Zadeh et al., 2017). The way forward for  
515 IUGG and other scientific unions and professional societies is to foster fundamental science for new discoveries and promote co-  
516 designed/co-productive ITD research. IUGG should place an emphasis on scientific investigations for interventions, that is, foster

517 action-oriented solutions of societal problems. For example, for disasters caused by natural hazard events, relevant research can  
518 be integrated and co-produced. A way of integration and co-production could be through the maturation of disaster science and  
519 through trans-disciplinary approaches aiming at in-depth investigations using systems analysis approaches. Systems analysis  
520 allows a disaster and/or disaster risk problem to be decomposed into its component parts to study how well they work, interact,  
521 and contribute to the overall aim of risk reduction. The final goal of the ITD approach is to issue recommendations for actions to  
522 reduce risks and to improve societal resilience (Cutter et al., 2015). Hence, IUGG should promote both disciplinary and ITD  
523 approaches in science education. Training and education within geoscience as well as practice domains can, through co-engaged  
524 and co-produced knowledge, enhance our understanding of the needs of vulnerable regions and populations, and enable  
525 practitioners and policymakers to use it to better effect.

526

527 One of the needs for co-productive research is to evaluate the quality and the success of ITD studies (NAS, 2004). IUGG has a  
528 role to play in such assessments. Together with other international scientific bodies, IUGG can lead in proposing and developing  
529 norms for ITD practice and geoscience education. For example, IUGG might develop appropriate standards and relevant skills to  
530 be mastered by students and scientists who participate in ITD education and research. The Union, via National Committees, could  
531 lobby national funding agencies to support ITD research projects and promote success stories of international ITD findings.

#### 532

#### 533 **10.4 Future of international scientific organizations**

534

535 Looking into the future, one may ask: Does modern science need international non-governmental organizations? Can the national  
536 and regional organizations replace them? What would happen if international scientific unions disappear? Historically, IUGG and  
537 other international scientific unions were set up as a response to the need for cooperation between nations, as many aspects of  
538 geosciences required international collaboration. Neither national nor regional professional societies (e.g., the American  
539 Geophysical Union [AGU], the Asia Oceanic Geosciences Society [AOGS] or the European Geosciences Union [EGU]) can truly  
540 replace international unions, as national and regional societies' major concern is typically their own nation or geographical region.  
541 Three possible scenarios could be drawn up for future development of the IUGG and other international unions (Ismail-Zadeh,  
542 2016): (1) integration of international geoscientific unions (e.g., GeoUnions of the ISC) and professional societies of geoscientists  
543 (e.g., AGU, AOGS, EGU); (2) reshaping of scientific priorities and structures of current geoscience organizations and their  
544 independent development in a cooperative way; and (3) competition between international, regional and national unions and  
545 societies.

546

547 The first scenario could possibly lead to the development of an international geosciences union with major regional branches in  
548 Africa, Central and South America, Asia/Oceania, and North America/Europe and with major disciplinary and interdisciplinary  
549 associations. After convergence, integration, and finally fusion of international geoscientific unions, on the one hand, and  
550 convergence or alliance of national and regional geoscience societies, on the other hand, the international geosciences union could  
551 then act as a (self-maintained financially) scientific body, coordinating activities of its regional branches and its scientific  
552 associations. This union could provide a full spectrum of services and benefits to its members: from scientific meetings and  
553 publications to involvement in the initiation, promotion, and implementation of national, regional and international scientific  
554 programs, scientific specialized commissions and working groups, and geoscientific services and outreach programs linking  
555 science to society and national and international policy. Such an international organization could become a single but powerful  
556 voice of Earth and space sciences and promote science to benefit humanity in a more efficient way.

557

558 The second scenario is more conservative. International scientific unions as well as national and regional societies of geoscientists  
 559 would continue their operations reshaping their structure and activities to meet modern scientific challenges. They could  
 560 establish/strengthen cooperation amongst themselves using a complementary rather than competitive approach. In the long-term,  
 561 this scenario may lead to a fusion (such as in the first scenario).

562

563 The third scenario would have a negative impact on international cooperation and development. National and regional societies of  
 564 geoscientists would continue to enhance their activities and to attract more and more scientists (especially those of younger  
 565 generations) to membership and to address national and regional policies encouraged by national governments or regional political  
 566 structures (e.g., the European Union). National scientific institutions or academies provide the funds necessary for adherence to  
 567 the international Unions. If these bodies in some developed countries were to adopt shortsighted policies by withdrawing from  
 568 membership of the Unions or reducing the amount of membership dues paid, the international Unions would lose the ability to  
 569 continue their operations and would cease to exist. The disappearance of international scientific unions would (i) lead to  
 570 “nationalism” in science (e.g., US, European or Chinese science), which may lead to replacement of “science for peace” by “science  
 571 for defense”, and to significant polarization; (ii) result in the disintegration of many important scientific programs already  
 572 established; (iii) harm (if not end) new international multidisciplinary programs; and (iv) become a destructive force for the world’s  
 573 scientific development and cooperation, as many developing nations get involved in scientific programs mostly via international  
 574 programs and through the activities of international scientific unions. Also, climatic and environmental change influences the world  
 575 globally, and disasters caused by natural hazard events do not respect political borders. We need globally-collected and shared data  
 576 and joint research cooperation efforts to understand, model and forecast these and many other phenomena and their societal  
 577 impacts. Our global networks of sensors and observatories, remote sensing missions, and international marine cruises to collect  
 578 data over the oceans, are crucial. Science with borders does not serve anyone well.

579

580 These scenarios describe a wide range of possibilities for the future development of IUGG and other international scientific unions,  
 581 and being extreme case scenarios the first and third scenarios are unlikely to be realized in full.

582

## 583     **10.5     Scientific challenges**

584

585 IUGG will continue to provide balanced, factual, and independent scientific information within its remit of Earth and space  
 586 sciences. Besides knowledge, which satisfies the curiosity of human beings related to the planet on which they live, and to the  
 587 Moon, planets, Sun, and stars, which they observe every day, IUGG provides information, understanding, and guidelines on  
 588 important society-relevant problems to deliver science for the benefit of humanity. Among the problems IUGG has been addressing  
 589 and will continue to address are: (i) climate variability and the contribution of CO<sub>2</sub> emission to its change to ensure continued  
 590 habitability of our planet for future generations; (ii) environmental pollution and its reduction in megacities to improve the quality  
 591 of life; (iii) natural hazards (e.g., hurricanes, floods, earthquakes, landslides) and mitigation/prevention of disasters to save lives  
 592 and infrastructure; (iv) weather, water, and soil conditions to assist farmers to grow food and provide other indispensable ecosystem  
 593 services; (v) mineral resources for future generations; (vi) clean water and reduction in contamination to preserve and enhance  
 594 human and ecosystem health; (vii) space and geodetic measurements for navigation of airplanes and satellites and other  
 595 applications; and (viii) pollution of oceans and seas, biodiversity and food security. IUGG will continue to increase geoscience  
 596 literacy through capacity building activities globally and especially in the developing world.

597

598 One of current challenges of scientific organizations, including IUGG, is to promote and to strengthen research cooperation  
599 fostering development for science policy within a complicated scientific landscape with emerging policy-oriented international  
600 programs. Science policy and diplomacy have been always essential components of IUGG activities and should remain in its core  
601 activities. Recent examples of science policy and diplomacy work include a synthesis report on science for disaster risk reduction  
602 presented at the UN Third World Conference on Disaster Risk Reduction in 2015 (Ismail-Zadeh and Cutter, 2015), a report on  
603 future of the ocean submitted to the G7 Science Ministers meeting in 2016 (Williamson et al., 2016), and publications on global  
604 change and the future of our planet (Beer et al., 2018), and disaster-related science diplomacy (Kontar et al., 2018).

605

606 Adopted by the UN General Assembly in 2015, the 2030 Agenda for Sustainable Development represents a new way of thinking  
607 about how better to link issues such as climate change, natural disasters and education. It intertwines social, economic, and  
608 environmental targets in 17 Sustainable Development Goals (SDGs; UN, 2015). IUGG has been contributing, and will continue to  
609 do so, to many of the SDGs; in particular, IUGG deals with promotion of studies in air pollution (sub-goal 3.9), climate and  
610 environmental issues (1.5, 2.5, 3.9, 11.6, and 13.3), hazard and disaster risk (1.5, 2.5, 11.5, 11b, 13.1, and 15.3), education and  
611 capacity building (4.7, and 4b), energy (7a), oceans and seas (14.1-14.3, 14a, and 14c), research and innovation (9.5, and 9b), water  
612 issues (3.9, 6.3-6.7, 15.1, and 15.3), and the Union continually seeks to improve its gender balance (5.5). All Union Associations,  
613 the Union Commissions such as GRC, CCEC, and UCDI, and the IUGG Committee on Capacity Building and Education will  
614 contribute to the SDGs mentioned above. For example, the IAMAS Commission on Atmospheric Chemistry and Global Pollution  
615 and the IAHS International Commission on Water Quality contribute to sub-goal 3.9 “to reduce the number of deaths and illnesses  
616 from [...] air, water [...] pollution and contamination”; the IASPEI-IAVCEI-IAPSO’s International Heat Flow and Tsunami  
617 Commissions advance knowledge on geothermal energy and tsunami, respectively; and IAPSO and IAHS contribute to issues of  
618 the ocean, seas and water (Ismail-Zadeh, 2016).

619

620 In 2016, IUGG issued its first Strategic Plan (IUGG-SP, 2016) and its implementation actions until 2023 (IUGG-IA, 2017). Among  
621 the important future key actions are to (i) promote the IUGG to its constituents, and to geoscientists, policy-makers and to society  
622 in general; (ii) encourage closer cooperation between the IUGG groups and more effective engagement with sister organizations,  
623 and other partner agencies; (iii) assist underrepresented geoscientists to more fully participate in international science activities;  
624 (iv) strengthen the effectiveness of the Union’s Council and the Executive Committee; (v) strengthen the promotion of fundamental  
625 research and education in the geosciences; and (vi) encourage more countries to become a member of the Union.

626

627 IUGG will maintain and enhance the links between scientists by initiating and developing various scientific, educational and  
628 outreach programs and scientific meetings, including the Union general assemblies and Association scientific assemblies, in  
629 cooperation with other international and intergovernmental organizations. It will continue to help in setting international  
630 geoscientific agendas, policies, recommendations, and guidelines.

631

632 IUGG played a significant role in the promotion of Earth and space sciences via international cooperation in the 20th century (the  
633 International Geophysical Year is a shining example of such cooperation). And the Union still has the potential to do so in the 21st  
634 century by playing an important role in Earth and space sciences, particularly in establishing the terms and conditions for  
635 international research cooperation, setting scientific standards and nomenclatures, preparing universal tools, and supporting and

636 promoting excellence, innovation, scientific freedom, inclusivity, diversity, and free access to geophysical data / services and to  
637 science education.

638

639 **11 IUGG leadership**

640

641 Finally, in this section we highlight the Presidents and Secretaries General, who have contributed significantly to the development  
642 of the Union and its Associations at the beginning of the 21<sup>st</sup> century.

643

644 Masaru Kono, President (1999–2003)



Masaru Kono (Japan, born in 1939) is a geophysicist, and his research is concerned with the magnetic field of the Earth, in particular, paleomagnetism and dynamo theory. Kono graduated from the University of Tokyo in 1963 and received his PhD from the same university in 1971. From 1968, he worked as Research Associate and then as Associate Professor at Geophysical Institute of the University of Tokyo. Since 1980, he held professor's positions at Tokyo Institute of Technology, the University of Tokyo, and Okayama University, until his retirement in 2005. Kono was IAGA Vice President (1991-1995), and then President (1995-1999). He also served as Vice Chair of the IUGG-SEDI, as a Member of the Scientific Boards for the International Geoscience Program of UNESCO and IUGS, for the Science Council of Japan, and for the International Ocean Drilling Program. He is Fellow of IUGG, AGU, Japan Geoscience Union, IAGA, and honorary Fellow of the Royal Astronomical Society.

645

646 JoAnn Joselyn, Secretary General (1999-2007)



JoAnn Joselyn (USA, born in 1943) is an astrogeophysicist who grew up during a period of, and achieved, amazing firsts, when advances in science and space exploration captured the imagination of people around the world. Following an undergraduate degree in applied mathematics at the University of Colorado (CU) at Boulder, she became the first woman to earn a doctoral degree at CU in astrogeophysics, the study of solar-planetary interactions. As a space scientist at the National Oceanic and Atmospheric Administration in Boulder, she showed that ejections of solar wind associated with disappearing solar filaments caused magnetic storms that can disrupt communications, electrical power transmission, space flight, and other emerging technologies. Joselyn became the first woman to be elected IAGA Secretary General (1995), and then the first woman and first American to be elected IUGG Secretary General. She is an IUGG Fellow.

647

648

649

Uri Shamir, President (2003–2007)



Uri Shamir (Israel, born in 1936) is a hydrologist. He graduated from the Technion - Israel Institute of Technology in 1962, and received his PhD in 1966 from the Massachusetts Institute of Technology, Cambridge, USA. Since 1979, Shamir has been Professor (Emeritus from 2004) in the Faculty of Civil and Environmental Engineering, and Founding Director (1992-2003) of the Stephen and Nancy Grand Water Research Institute, at the Technion. In 1992, Shamir has been Visiting Professor in various universities and research institutes in the USA and Canada, and was Chairman of the Israeli Association of Hydrology. He served as IAHS President (1991-1995), IUGG Vice President (1995-2003), and a Member of the ICSU Executive Board (2005-2011). He chaired the Technical Advisory Committee of the World Water Assessment Programme (WWAP-TAC), the UN water programme led by UNESCO. He is Fellow of IUGG, AGU, American Society of Civil Engineers, and Foreign Member of the Spanish Academy of Science.

650

651 Tom Beer, President (2007–2011)



Tom Beer (Australia, born in 1947) is an atmospheric scientist. Beer graduated from the University of Sydney in 1966, and obtained his PhD from the University of Western Ontario in 1971. He led the Climate Research Program of the Centre for Australian Weather and Climate Research, a partnership between the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Australian Bureau of Meteorology. Beer served IUGG as Bureau Member and Vice President before he was elected President. Beer was a founder of the IUGG GRC in 2000, becoming its first Chair, and of the IUGG CCEC in 2011, also becoming its first Chair. He served on the ICSU Committee for Scientific Planning and Review. He was awarded Doctor of Science degree by the University of Canterbury in New Zealand. He was elected Fellow of several societies and foreign member of the Hungarian Academy of Sciences.

652

653 Harsh Gupta, President (2011–2015)



Harsh Gupta (India, born in 1942) is a geoscientist and seismologist. He received his BSc (Hons) and MSc degrees from the Indian School of Mines, Dhanbad before he obtained his PhD degree from the Indian Institute of Technology, Roorkee. He worked in the University of Texas at Dallas (USA) before he returned to India and became Director of the Centre for Earth Science Studies, Thiruvananthapuram in 1982. He kept positions of Vice Chancellor of Cochin University of Science and Technology, Director of the National Geophysical Research Institute (NGRI) in Hyderabad, Secretary at the Department of Ocean Development of the Government of India. At present, Gupta is a Raja Ramanna Fellow at NGRI. Before Gupta was elected IUGG President, he served the IUGG Bureau as Member (1999-2007) and Vice President (2007-2011). He served on the ICSU Committee for Scientific Planning and Review. Gupta held leadership roles in several national and international scientific organizations. He is AGU Fellow and member of several national academies.

654

655 Michael Sideris, President (2015–2019)



Michael Sideris (Canada, born in 1958 in Greece) is a geodesist with the expertise in the fields of satellite Earth observation. He received his Diploma (Hons) from the National Technical University of Athens, Greece in 1981, M.Sc. (1984) and PhD (1987) from the University of Calgary, Canada. Since 1988 Sideris has been working in the Department of Geomatics Engineering at the University of Calgary, where he is currently Professor and Associate Head (Graduate Studies). He has also served the university as Associate Dean of the Faculty of Graduate Studies and Associate Dean Research of the Schulich School of Engineering. He has been visiting Professor at several Asian, Australian, European, and South American universities/institutes. He was IAG Vice President (2003-2007) and President (2007-2011), and IUGG Vice President (2011-2015). Since 2016 Sideris has been serving on the GEO Program Board. He is an A. von Humboldt International Research Fellow, IAG Fellow, and IAG Honorary President.

656

657 Kathryn Whaler, Vice President (2015-2019)



Kathryn Whaler (UK, born in 1956) is a geophysicist with expertise in the fields of core dynamics, crustal magnetization, magnetotellurics, and geomagnetic observations. She received BSc in Mathematical Physics from the University of Sussex in 1977 and PhD from the University of Cambridge in 1981. Whaler joined the University of Leeds in 1983 as a lecturer, and in 1994, she moved to the University of Edinburgh to take up the Chair of Geophysics. She was the President of the Royal Astronomical Society (2004-2006). She served IAGA as Executive Committee Member (2003-2007), Vice President (2007-2011), and President (2011-2015) before she was elected IUGG Vice President (2015-2019). She has visited the NASA's Goddard Space Flight Center, Harvard University, the University of California at San Diego (as Green Scholar), Victoria University of Wellington, and Göttingen University (as Gauss Professor). Whaler is Fellow of AGU, the Institute of Physics, and the Royal Society of Edinburgh.

658

659 Alik Ismail-Zadeh, Secretary General (2007 - 2019)



Alik Ismail-Zadeh (Germany/Russia, born 1961 in Azerbaijan) is a mathematical geophysicist, graduated from Baku State University (mathematics) and Lomonosov Moscow State University (physics) before being awarded PhD and DSc degrees in geophysics from the Russian Academy of Sciences (RAS). He has been Chief Scientist/Research Professor of RAS in Moscow since 1998, and Senior Scientist at Karlsruhe Institute of Technology, Germany since 2001. He was a visiting professor at several universities including in China, France, Japan, Sweden, UK, and USA. He is a co-founder of the IUGG-GRC (Chair, 2004-2007) and a co-founder of the AGU Natural Hazard Section (Chair, 2009-2012). He has served or is serving on governing or advisory committees of international and intergovernmental organizations and programs including AGU, CTBTO, UNISDR, and

UNESCO. He was elected the first ISC Secretary (2018-2021). He is elected member of Academia Europaea and honorary Fellow of the Royal Astronomical Society.

660

## 661    12      Conclusion

662

663    Since its formation in 1919, IUGG has been committed to initiating, promoting and coordinating international  
664    scientific studies and observations of the Earth and its environment in space. Today, as a vibrant modern scientific union of nations  
665    and individual scientists from all over the world, the Union is proud to promote research, science education, and capacity building  
666    via international cooperation, linking scientific knowledge to societal needs, and working toward a sustainable Earth (Ismail-  
667    Zadeh, 2016).

668

669    IUGG's centennial history (Appendix 2) illustrates how hundreds of thousands of Earth and space scientists have developed and  
670    cooperated in international research to benefit society and promoted fundamental science as well as science for society. The Union  
671    encourages the application of this knowledge to societal needs, such as the mitigation of impacts from natural hazard events, the  
672    sustainable use of energy and mineral resources, and environmental preservation (Ismail-Zadeh and Beer, 2009). Particularly,  
673    IUGG responded vigorously to the challenges associated with climatic and environmental changes, disasters, water issues and  
674    many others, promoting research and scientific cooperation. The Union has played an important regulatory role in geodetic and  
675    geophysical sciences, particularly in establishing the terms and conditions for international research cooperation, setting scientific  
676    standards and nomenclatures, preparing universal tools and data products, among other aspects. IUGG brought state-of-the-art  
677    science to less-affluent countries through capacity building and science education. The Union links scientists via its scientific,  
678    educational and outreach programs to programs of intergovernmental organizations and assists in establishing international  
679    scientific agendas, policies, recommendations, and guidelines (Ismail-Zadeh, 2016).

680

681    Since the beginning of the 21<sup>st</sup> century, IUGG has been involved in the process of reshaping its structure and activities to meet its  
682    scientific and organizational needs (see Ismail-Zadeh, 2016, for more detail). The most notable of these changes are:

683

- To make the Union more vibrant in terms of decision making, the Council has become a continuously operating body.
- Scientists from any country are now eligible to hold most positions within the IUGG family with a few exceptions, which can only be held by scientists from Member Countries.
- Four standing Union Committees on Membership Issues, Capacity Building and Education, Honor and Recognition, and Visioning have been formed to help the Union reshape its membership structure and science education programs, establish Union awards and medals, and develop IUGG strategic planning.
- Affiliate membership of IUGG was established to strengthen cooperation with geoscientific organizations worldwide.
- Three Union Commissions – Data and Information, Climatic and Environmental Change, and Planetary Sciences – as well as the Union Working Group on History have been established to coordinate activities across IUGG associations and other international organizations on relevant scientific topics.
- IUGG established a new Grants Program to support interdisciplinary projects, which will explore new scientific ideas and develop future international initiatives.
- IUGG renewed its publication policy, and agreed to produce a series of works entitled “Special Publication of the IUGG” published by the Cambridge University Press.

- 697 - The Union put forward a new initiative to enhance geophysical and geodetic science education centered on less-affluent  
 698 areas of the world and developed a fruitful cooperation with the Abdus Salam International Center for Theoretical Physics.  
 699 - IUGG established the honors program to recognize Earth and space scientists for their outstanding contributions to  
 700 geodesy and geophysics and for unselfish international scientific cooperation.

701

702 Changes such as these enable the Union to do its best work in support of its mission, which is to continue to advance, strengthen  
 703 and promote Earth and space sciences for the benefit of humanity, through international research cooperation and education, and  
 704 to communicate the knowledge to governments and policy-makers (IUGG-SP, 2016). The application of Earth and space sciences  
 705 to societal needs requires coordinated efforts between IUGG and other scientific bodies and stakeholders including professional  
 706 societies and intergovernmental organizations. IUGG will continue to evolve throughout the coming decades in step with the  
 707 changing world of science and its international organizations, responding to the challenging problems of society.

708

709 **Appendix 1. Member Adhering Bodies of IUGG (1919-2019)**

#	Members	Dates of admission & termination	#	Members	Dates of admission & termination
1	ALBANIA	1997	51	KOREA	1960
2	ALGERIA	1971-2006, 2018	52	KOREA DEM. REP.	1967-2000
3	ARGENTINA	1927	53	LEBANON	1967-2003
4	ARMENIA	2000	54	LIBYA	1979-1996
5	AUSTRALIA	1919	55	LUXEMBOURG	1971
6	AUSTRIA	1948	56	MACEDONIA, F.Y.R.	1995-2001, 2010
7	AZERBAIJAN	2010	57	MADAGASCAR	1967-1995
8	BELGIUM	1919	58	MALAYSIA	1967-2002
9	BOLIVIA	1960-2000, 2006	59	MAURITIUS	2003
10	BOSNIA & HERZEGOVINA	2003	60	MEXICO	1922
11	BRAZIL	1922	61	MONACO	1967-2013
12	BULGARIA	1930	62	MONGOLIA	1995-2001
13	BURUNDI	1987-1995	63	MOROCCO	1924
14	CANADA	1919	64	MOZAMBIQUE	1983
15	CHILE	1924	65	MYANMAR (BURMA)	1957-2003
16	CHINA – CAST	1977	66	NEPAL	1975-1987
17	CHINA – Acad. Sci. in Taipei	1995	67	NETHERLANDS	1925
18	COLOMBIA	1938-1971, 2000	68	NEW ZEALAND	1927
19	CONGO DEM.REP. (*)	1991-1997, 2004	69	NICARAGUA	2014
20	COSTA RICA	2010	70	NIGERIA	1971
21	CROATIA	1992	71	NORWAY	1923
22	CUBA	1960-1996	72	PAKISTAN	1952
23	CZECH REP.	1993	73	PERU	1925-1979, 2000
24	DENMARK	1923	74	PHILIPPINES	1951-2015
25	DOMINICAN REP.	1957-1971	75	POLAND	1924
26	EGYPT	1924	76	PORTUGAL	1919
27	ESTONIA	1991	77	ROMANIA	1930
28	ETHIOPIA	1952-2000	78	RUSSIA(**)	1954
29	FINLAND	1927	79	SAUDI ARABIA	1971-2001, 2012
30	FRANCE	1919	80	SENEGAL	1960-1995
31	GEORGIA	2009	81	SERBIA (***)	1996-2006, 2018
32	GERMANY	1951	82	SIERRA LEONE	1967-1983
33	GHANA	1957-1987, 2006	83	SLOVAK REP.	1993
34	GREECE	1922-2003, 2008	84	SLOVENIA	1994
35	GUATEMALA	1957-2000	85	SOUTH AFRICA	1924
36	GUINEA	1987-1995	86	SPAIN	1922
37	HAITI	1956-1971	87	SUDAN	1955-2000

38	HUNGARY	1930	88	SWEDEN	1923
39	ICELAND	1967	89	SWITZERLAND	1923
40	INDIA	1947	90	SYRIA	1948-1995
41	INDONESIA	1951	91	TANZANIA	1975-2000
42	IRAN	1957	92	THAILAND	1923
43	IRAQ	1983-1996	93	TUNISIA	1927-2001
44	IRELAND	1946	94	TURKEY	1949
45	ISRAEL	1951	95	UK	1919
46	ITALY	1919	96	URUGUAY	1924-2000, 2019
47	IVORY COAST	1975-1996	97	USA	1919
48	JAPAN	1919	98	VENEZUELA	1975-2008
49	JORDAN	1979	99	VIETNAM	1931
50	KENYA	1975-1997	100	ZIMBABWE	1967-2000

710

(\*) Adhesion in 1991 under the name Zaire, membership terminated in 1997

711

(\*\*) Adhesion in 1954 under the name of the USSR; Russia since 1992

712

(\*\*\*) Adhesion in 1996 under the name of the Fed. Rep. of Yugoslavia which was changed to Serbia & Montenegro in 2003, and changed to Serbia in 2018.

713

714

715

716

717

## Appendix 2. IUGG Timeline (1919-2019)

718

YEAR	ACTIVITY	PLACE
1919	IUGG was founded with six Sections (Geodesy, Terrestrial Magnetism and Electricity, Meteorology, Physical Oceanography, Seismology, and Volcanology)	Brussels, Belgium
1922	Seventh Section, Scientific Hydrology, was added	Rome, Italy
1932/1933	The Second International Polar Year	
1933	Sections were renamed International Associations	Lisbon, Portugal
1946	Extraordinary General Assembly to reconstitute IUGG following WWII	Cambridge, UK
1946	IUGG and U.N. Education, Scientific and Cultural Organization (UNESCO) signed a working agreement	Paris, France
1951	The International Association (IA) of Seismology became the IA of Seismology and Physics of the Earth's Interior (IASPEI)	Brussels, Belgium
1952	First issues of the IUGG Bulletin, which became the IUGG Chronicle (ceased in 1995)	
1954	IUGG and the World Meteorological Organization (WMO) signed a working agreement	Geneva, Switzerland
1957/1958	The International Geophysical Year (IGY)	
1957	The IA for Terrestrial Magnetism and Electricity became the IA for Geomagnetism and Aeronomy (IAGA)	Toronto, Canada
1960	Cooperation with the Intergovernmental Oceanographic Commission of UNESCO started	Paris, France
1967	First use of the present day IUGG logo	Zurich, Switzerland

1967	The IA of Volcanology became the IA of Volcanology and Chemistry of the Earth's Interior (IAVCEI)	Zurich, Switzerland
1967	The IA of Physical Oceanography became the IA for the Physical Sciences of the Ocean (IAPSO)	Zurich, Switzerland
1971	The IA of Scientific Hydrology became the IA of Hydrological Sciences (IAHS)	Moscow, USSR (now Russia)
1971	The Inter-Association Committee on Mathematical Geophysics (now the Union Commission on Mathematical Geophysics - CMG) was established	Moscow, USSR (now Russia)
1975	Cooperation with the International Hydrological Program of UNESCO started	Paris, France
1987	Union Committee on the Study of the Earth's Deep Interior (now the Union Commission SEDI) was established	Vancouver, Canada
1988	The first International Terrestrial Reference Frame is released by the IAG	
1991	The International Lithosphere Program becomes an IUGS/IUGG inter-Union body	Vienna, Austria
1995	The International Association of Meteorology and Atmospheric Physics (IAMAP) becomes the IA of Meteorology and Atmospheric Sciences (IAMAS)	Boulder, USA
1998	IUGG website established	
2000	Union Commission on Geophysical Risk and Sustainability (GRC) was established	
2001	IUGG monthly E-Journal established	
2003	Early Career Scientist Union Symposium series was established	Sapporo, Japan
2004	ICSU GeoUnions consortium was established	Paris, France
2007	International Association for Cryospheric Sciences was established	Perugia, Italy
2008	The IUGG Grants Program was established	
2007/2008	The Electronic Geophysical Year (eGY) The International Heliophysical Year (IHY) The International Year of Planet Earth (IYPE) The International Polar Year (IPY)	
2008	The Union Commission for Data and Information (UCDI) was established	
2011	IUGG and the Abdus Salam International Centre for Theoretical Physics (ICTP) agreed to develop a joint geophysical and geodetic science education program	Trieste, Italy
2011	Affiliate Membership and Honorary Membership were established	Melbourne, Australia
2012	The Union Commission on Climatic and Environmental Change (CCEC) was established	
2012	The Working Group on History was established	

2012	IUGG signed a Memorandum of Agreement with the Cambridge University Press to publish a series of works entitled "Special Publications of the IUGG"	
2013	IUGG became a Participating Organization of the Group on Earth Observations (GEO)	Geneva, Switzerland
2015	First IUGG Awards (Gold Medal, Silver Medal, IUGG Fellows, and Early Career Scientist Award) presented	Prague, Czech Republic
2015	The Union Commission on Planetary Sciences (UCPS) was established	
2016	New Association logos designed and approved	
2016	Strategic Plan 2016-2023 and its Implementation Plan were adopted	
2017	IUGG became an Observer Organization of the Intergovernmental Panel on Climate Change (IPCC)	Geneva, Switzerland
2019	IUGG Centennial	Montreal, Canada

719

720 Acknowledgments. The authors are thankful to Jaime Urrutia-Fucugauchi, Aksel W. Hansen, and Kristian Schlegel (topic editor)  
 721 for the review of the paper and their comments.

722

## 723 References

724

- 725 Adams, J.: The fourth age of research, *Nature* 497, 557-560, 2013.  
 726 AIP: Records of the International Union of Geodesy and Geophysics, 1922-2000 (bulk 1955-1998). Description of collection.  
 727 American Institute of Physics. Center for History of Physics, 2019. Available at: <https://history.aip.org/ead/20010000.html>  
 728 (accessed on 16.01.2019).  
 729 Ashford, O. M.: The launching of the Global Atmospheric Research Programme (GARP), *Weather*, 37, 265-272, 1982.  
 730 Beer, T., Li, J., and Alverson, K.: *Global Change and Future Earth: The Geoscience Perspective*. Cambridge University Press,  
 731 Cambridge, 2018.  
 732 Bolin, B. (2007). *A History of the Science and Politics of Climate Change: The Role of the Intergovernmental Panel on Climate  
 733 Change*. Cambridge: Cambridge University Press.  
 734 Cartlidge, E.: Italy's supreme court clears L'Aquila earthquake scientists for good, *Science*, doi:10.1126/science.aad7473, 2015.  
 735 Cutter, S., Ismail-Zadeh, A., Alcántara-Ayala, I. et al.: Pool knowledge to stem losses from disasters, *Nature*, 522, 277-279, 2015.  
 736 Ismail-Zadeh, A.: Geoscience international: the role of scientific unions, *History of Geo- and Space Sciences*, 7, 103-123, 2016.  
 737 Ismail-Zadeh, A.: Mapping IUGG to Sustainable Development Goals, *IUGG E-Journal*, 16(11), 1-2, 8-10, 2016.  
 738 Ismail-Zadeh, A. T., and Beer, T.: International cooperation in geophysics to benefit society, *Eos*, 90(51), 493, 501-502, 2009.  
 739 Ismail-Zadeh, A., and Cutter, S. (eds.): *Disaster Risks Research and Assessment to Promote Risk Reduction and Management*.  
 740 International Council for Science and the International Social Sciences Council, Paris, France, 2015.  
 741 Ismail-Zadeh, A., and Joselyn, J.A.: IUGG: Beginning, establishment and early development (1919-1939), *History of Geo- and  
 742 Space Sciences*, Special Issue “The International Union of Geodesy and Geophysics: From Different Spheres to a Common  
 743 Globe”, 2019.

- 744 Ismail-Zadeh, A., Urrutia Fucugauchi, J., Kijko, A., Takeuchi, K., and Zaliapin, I. (eds.): Extreme Natural Hazards, Disaster Risks  
745 and Societal Implications, Cambridge University Press, Cambridge, 2014.
- 746 Ismail-Zadeh, A., Cutter, S. L., Takeuchi, K., and Paton, D.: Forging a paradigm shift in disaster science, Nat. Hazards, 86, 969-  
747 988, 2017.
- 748 IUGG Archives: Resolutions of the Union adopted at the XXIII General Assembly, Sapporo, Japan, 2003. Available at:  
749 <http://www.iugg.org/resolutions/sapporo03.pdf> (accessed on 16.01.2019)
- 750 IUGG Archives: Resolutions of the Union adopted at the XXIV General Assembly, Perugia, Italy, 2007. Available at:  
751 <http://www.iugg.org/resolutions/perugia07.pdf> (accessed on 16.01.2019).
- 752 IUGG Archives: Resolutions of the Union adopted at the XXV General Assembly, Melbourne, Australia, 2011. Available at:  
753 [http://www.iugg.org/resolutions/IUGG%20Resolutions%20-%20XXV%20GA%20-%20Melbourne%20\(English\).pdf](http://www.iugg.org/resolutions/IUGG%20Resolutions%20-%20XXV%20GA%20-%20Melbourne%20(English).pdf)  
754 (accessed on 16.01.2019).
- 755 IUGG Archives: Resolutions of the Union adopted by the Council at the XXVI General Assembly, Prague, Czech Rep., 2015.  
756 Available at: <http://www.iugg.org/resolutions/IUGGResolutions2015.pdf> (accessed on 16.01.2019).
- 757 IUGG-SP: IUGG Strategic Plan 2016-2023, 2016. Available at: [http://www.iugg.org/special/IUGG\\_StrategicPlan\\_2016-2023.pdf](http://www.iugg.org/special/IUGG_StrategicPlan_2016-2023.pdf)  
758 (accessed on 14.10.2018).
- 759 IUGG-IA: Implementation Actions for the IUGG Strategic Plan 2016-2023, 2017. Available at:  
760 [http://www.iugg.org/special/IUGG\\_ImplementationActions4SP.pdf](http://www.iugg.org/special/IUGG_ImplementationActions4SP.pdf) (accessed on 14.10.2018).
- 761 Joselyn, J.A., and Ismail-Zadeh, A.: IUGG Evolves (1940-2000), History of Geo- and Space Sciences, Special Issue “The  
762 International Union of Geodesy and Geophysics: From Different Spheres to a Common Globe”, 2019.
- 763 Kontar, Y.Y., Beer, T., Berkman, P. A., Eichelberger, J.C., Ismail-Zadeh, A., Kelman, I., LaBrecque, J.L., Sztein, A.E., and Zaika,  
764 Y.: Disaster-related science diplomacy: advancing global resilience through international scientific collaborations, AAAS  
765 Science & Diplomacy, 7(2), 2018. <http://www.science-diplomacy.org/article/2018/disaster-related-science-diplomacy-advancing-global-resilience-through-international>
- 766 Li, J., Swinbank, R., Grotjahn, R., and Volkert, H.: Dynamics and Predictability of Large-Scale, High-Impact Weather and Climate  
767 Events. Cambridge University Press, Cambridge, 2016.
- 768 NAS: Facilitating Interdisciplinary Research. Report of the Committee on Facilitating Interdisciplinary Research of the National  
769 Academies. National Academies Press, Washington, D.C., 2004.
- 770 Rohde, H.: Bert Bolin (1925-2007) – a world leading climate scientist and science organiser. Tellus B 65, 1-6, 2013.
- 771 Sparks, R. and Hawkesworth, C., eds.: The State of the Planet: Frontiers and Challenges in Geophysics, American Geophysical  
772 Union, Washington D.C., 2004
- 773 UN: Transforming our World: The 2030 Agenda for Sustainable Development. A/RES/70/1. United Nations, New York, 2015.  
774 Available at: <https://sustainabledevelopment.un.org/index.php?page=view&type=111&nr=8496&menu=35> (accessed on  
775 16.01.2019).
- 776 Weart, S. R.: The evolution of international cooperation in climate science, Journal of International Organizations Studies, 3(1),  
777 41-59, 2012.
- 778 Williamson, P., Smythe-Wright, D., and Burkill, P., eds.: Future of the Ocean and its Seas: a non-governmental scientific  
779 perspective on seven marine research issues of G7 interest. ICSU-IAPSO-IUGG-SCOR, Paris, 2016. Available at:  
780 [http://www.iugg.org/policy/Report\\_FutureOcean\\_G7\\_2016.pdf](http://www.iugg.org/policy/Report_FutureOcean_G7_2016.pdf) (accessed on 14.10.2018)
- 781
- 782

**Table 1. International Years initiated or supported by IUGG (2000-2019)**

<i>International Year of Planet Earth (IYPE; 2007 - 2010)</i>	IYPE ( <a href="http://yearofplanetearth.org">http://yearofplanetearth.org</a> ) was the first UN Year for Earth Sciences initiated and led by the International Union of Geological Sciences. In December 2005, the UN General Assembly proclaimed 2008 as the UN Year of Planet Earth – Earth Sciences for Society. IUGG had supported the drive toward IYPE since 2003. Nine science objectives and relevant teams were established: hazards (chaired by Tom Beer, IUGG President 2007-2011); groundwater; climate; oceans; Earth and health; resources; megacities; deep Earth; and soils. IUGG scientists were valued members of many of these teams. A series of monographs were published that report on each of these topics ( <a href="https://link.springer.com/bookseries/8096">https://link.springer.com/bookseries/8096</a> ).
<i>International Polar Year (IPY; 2007 - 2008)</i>	Previous IPYs (1882-1883, 1932-1933, and IGY 1957-58) successfully promoted unprecedented exploration and discoveries, and fundamentally changed how science was conducted in Polar Regions. The fourth IPY ( <a href="http://ipy.org">http://ipy.org</a> ) brought together tens of thousands of investigators to collect and analyze data in diverse disciplines in the physical, life, and social sciences, including engagement of the native communities. The IPY Data and Information Service (IPYDIS) addressed the challenge of data coordination. The IPYDIS participated in the IUGG-led Electronic Geophysical Year (eGY) and applied eGY principles to IPY data management. Building on the precedent set by the Antarctic Treaty, the data generated during the campaign have been archived in the Polar Information Commons, an open-access information resource about the Earth's polar regions ( <a href="http://www.polarcommons.org">http://www.polarcommons.org</a> ). Major publications and conferences emerged from the IPY. The final IPY conference, From Knowledge to Action, was held in Montréal, Canada in 2012.
<i>Electronic Geophysical Year (eGY; 2007 – 2008)</i>	Initiated by the International Association of Geomagnetism and Aeronomy (IAGA), the opening ceremony was held during the IUGG General Assembly in Perugia, Italy in 2007. The Electronic Geophysical Year ( <a href="http://www.egy.org">http://www.egy.org</a> ) provided the international framework for mobilizing the science community to achieve a step increase in making past, present, and future geoscientific data readily, rapidly, conveniently, and openly available. The eGY promoted the development of a network of virtual observatories and focused on themes of electronic data location and access, permission and release of data, conversion of data into modern digital form, data preservation, outreach, and capacity building in developing countries, especially in Africa.
<i>International Heliophysical Year (IHY; 2007 - 2008)</i>	Several IAGA commissions participated in this broad international effort which addressed all aspects of the connected Sun-Solar system while also engaging the public, and students all over the world. It was coordinated with the UN Basic Space Science Initiative through their Office for Outer Space Affairs. The IHY Organizing Committees included 75 nations, and the activities involved representation from nearly all of the 192 United Nations member states. More information on the IHY and its legacy, the International Space Weather Initiative, can be found at: <a href="http://www.unoosa.org/oosa/en/ourwork/psa/bssi/ihy2007.html">http://www.unoosa.org/oosa/en/ourwork/psa/bssi/ihy2007.html</a>
<i>International Year of Deltas (IYD; 2013-2014)</i>	This year focused on the value and vulnerability of river deltas worldwide. IYD was co-sponsored by IUGG under the auspices of the International Association of Hydrological

	Sciences (IAHS) and the International Association for the Physical Sciences of the Oceans (IAPSO), who appointed liaisons to the IYD Scientific Committee. It was extended in 2015 to the International Decade of Deltas programme. More information on the IYD: <a href="https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2011EO400006">https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2011EO400006</a>
<i>International Year of Global Understanding (IYGU; 2016-2017)</i>	Co-sponsored by IUGG, IYGU was initiated by the International Geographical Union and endorsed by ICSU, ISSC and the International Council for Philosophy and Human Sciences (CIPSH). IYGU aimed to build bridges between global thinking and local action by addressing sustainable development and fostering policies on critical global challenges such as climate change, food security and migration. In 2018, this year was extended to the International Decade of Global Understanding programme. More information on the IYGU: <a href="http://www.global-understanding.info/">http://www.global-understanding.info/</a>

785

786

787

788 **Table 2. IUGG General Assemblies from 1999 to 2019, and IUGG Presidents and Secretaries General elected**

No. GA	Year	Place	No. attendees	No. Member countries	President	Secretary General
XXIII	2003	Sapporo, Japan	4151	65	U. Shamir (Israel, 2003-2007)	J. A. Joselyn (USA, 1999-2007)
XXIV	2007	Perugia, Italy	4375	66	T. Beer (Australia, 2007-2011)	A. Ismail-Zadeh (Germany/Russia, 2007-2019)
XXV	2011	Melbourne, Australia	3392	70	H. Gupta (India, 2011-2015)	
XXVI	2015	Prague, Czech Rep.	4231	71	M. Sideris (Canada, 2015-2019)	
XXVII	2019	Montreal, Canada		72		

789

790

791

792 **Figure Captions**

793

794 Figure 1: Opening ceremony of the XXIII IUGG General assembly. S .Uyeda, Chair of the Local Organizing Committee  
795 (welcoming the assembly's participants) on the left, and His Majesty The Emperor of Japan and The Empress of Japan on the right  
796 of the photo (courtesy: S. Uyeda).

797

798 Figure 2: IUGG's congratulations on the occasion of the birth of IACS. Featured is Georg Kaser, the first IACS President  
799 (source: IUGG archives)

800

801 Figure 3: Award ceremony at the XXVI IUGG General Assembly, Prague, Czech Republic, 2015

802



Fig. 1

Joselyn et al., 2019



Fig. 2

Joselyn et al., 2019



Fig. 3

Joselyn et al., 2019