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INTERNATIONAL COOPERATION IN GEOPHYSICS TO BENEFIT SOCIETY

Humanity's very existence depends on the bounties of the Earth, oceans, and atmosphere, yet often these elements turn against citizens of this planet. Each year earthquakes, drought, storms, volcanoes, disturbances in the Earth's magnetic field, and other natural hazards affect communities in ways that range from inconvenience through to mass destruction. Studies of the Earth and its environment in space help scientists to anticipate and warn of such natural disasters and help keep people out of harm's way. Studies that reveal the secrets of the Earth's natural resources can improve the quality of life for Earth's growing populations. And scientific understanding of the Earth's processes can help to reduce humanity's destructive impact on the environment and help promote sustainable management of its resources.

These processes know no political boundaries and therefore require organized international cooperation. Formal international geophysical cooperation was established ninety years ago through the creation of the International Union of Geodesy and Geophysics (IUGG). Several national (e.g. American Geophysical Union), and most recently regional (e.g. European Geosciences Union, Asia Oceania Geosciences Society) geophysical unions and societies have also grown in the past century.

Today, such organizations play a significant role in fostering worldwide cooperation in geophysical research. As Earth sciences become exceedingly complex with and interwoven within its disciplines, encouraging relationships among international, national and regional geoscientific bodies becomes increasingly important. Through analyzing the history of international cooperation in geophysics, scientists gain key insights into strengthening cooperation between societies focused on Earth sciences

Early Cooperation Efforts

Formal international cooperation in geophysical subdisciplines began more than two centuries ago when Alexander von Humboldt (1769-1859), organized widespread simultaneous magnetic observations in the first decade of the nineteenth century after his return from South America. Later, Carl Friedrich Gauss (1777-1855) founded the Magnetic Union, which fostered the institution of magnetic observatories during 1836-1841. This union promoted a cooperative scheme of simultaneous observation in which fifty observatories, distributed over five continents, took part.

Soon after, other geosciences disciplines established international cooperation efforts. In 1853, under the influence of Matthew Fontaine Maury (1806-1873), oceanography and maritime meteorology became important data collection aspects of the United States Naval Observatory. Later, in 1900, Prince Albert I of Monaco, who devoted time and resources to oceanography, granted his patronage to the establishment of the International Marine Association.

International cooperation in geodesy can trace its roots back to the nineteenth century, through the important contributions of Friedrich Wilhelm Bessel (1784-1846) and Gauss. In 1861, Prussian General and geodesist Johann Baeyer (1794-1885), a student of Bessel, proposed that the States of Europe should work together on the measurement of the size and shape of the Earth

and described methods to achieve this aim. The King of Prussia accepted the proposal and invited the countries concerned to subscribe to the plan. In 1862 the geodetic community assembled in Berlin and established Mitteleuropäische Gradmessung, which became the Association Géodésique Internationale (International Association of Geodesy) in 1886.

The International Meteorological Congress (14-16 August 1872, Leipzig) laid a foundation for a worldwide cooperation in meteorology. The international cooperation in seismology began in 1901 at the first International Conference on Seismology (11-13 April 1901, Strasbourg), and the International Seismological Association was founded in 1904.

Though these early efforts were highly successful, discussion between societies was often limited, forcing scientists to brainstorm a new model.

A Broader Approach: The International Union of Geodesy and Geophysics

By the outbreak of World War I in 1914, international organizations for geodesy, seismology, meteorology (which took geomagnetism and geoelectricity under its wing), and oceanography had already arisen. The war interrupted the operation of these bodies, though some were kept active by then neutral nations.

During the war, some scientific leaders from the allied nations gave thought to the post-war renewal of international scientific cooperation. In 1918 these leaders met in London and Paris and decided to withdraw from the pre-existing international organizations and to found a new body, the International Research Council, the predecessor of the International Council for Science (ICSU). This Council was set up at Brussels, Belgium, in 1919 with the purposes to coordinate international activity in the different branches of science, to stimulate the creation of international scientific associations or unions, and to guide international scientific activity in the scientific branches where no such organizations existed.

At once, after its own formation, the International Research Council instituted several international scientific unions. First among these was the International Union of Geodesy and Geophysics (IUGG, http://www.iugg.org). IUGG was established on 28 July 1919 as an international, non-governmental, non-profit organization, in place of several pre-existing organizations that were independent and separate from one another.

IUGG is dedicated to promoting and coordinating scientific studies of the Earth (physical, chemical, and mathematical) and its environment in space. These studies include the shape of the Earth; its gravitational and magnetic fields; the dynamics of the Earth as a whole and of its component parts; the Earth's shape, surface, internal structure, composition and tectonics; the generation of magmas; volcanism and rock formation; the hydrological cycle including snow and ice; all aspects of the oceans; the atmosphere, cryosphere, ionosphere, magnetosphere and solar-terrestrial relations; and analogous problems associated with the Moon and other planets. The Union encourages the application of this knowledge to societal needs, such as the sustainable use of energy and mineral resources, mitigation of natural hazards, and environmental preservation.

Only nine countries adhered to the IUGG in its inaugural year: Australia, Belgium, Canada, France, Great Britain, Italy, Japan, Portugal, and the United States. From the outset, IUGG had six sections (re-named associations in 1930): geodesy, seismology, meteorology, terrestrial magnetism and electricity, physical oceanography, and volcanology. The hydrology section was established three years later in 1922 at the first General Assembly of IUGG.

Today, IUGG is comprised of eight semi-autonomous International Associations, each responsible for a specific range of topics or themes within the overall scope of Union activities: cryospheric sciences (IACS), geodesy (IAG), geomagnetism and aeronomy (IAGA), hydrological sciences (IAHS), meteorology and atmospheric sciences (IAMAS), physical sciences of the oceans (IAPSO), seismology and physics of the Earth's interior (IASPEI), volcanology and chemistry of the Earth's interior (IAVCEI). The Union has expanded to include 67 countries of Africa, America, Asia, Europe, and Oceania, giving scientists from across the world the advantage of close cooperation, the opportunity to share data, and recurrent easy opportunities for open scientific discussion.

IUGG: Fostering Collaborative Efforts

In addition to facilitating science, as all professional societies do, IUGG and the Associations also work to enable science through forming consensuses on the best investigations to promote understanding, given natural and political constraints. The international associations of IUGG also work to set standards for research and agree on definitions and algorithms. Additionally, participants pass resolutions on important issues where all agree, such as the vote to support the Nuclear Test Ban Treaty. IUGG makes research visible to the international scientific community, to government agencies, to industry, and to the public in general through their education and outreach activities. These activities include classes, workshops, handbooks, manuals, guides for accepted practice, maps, videos, and published surveys. In addition, several associations work to have important printed materials translated into several languages to increase their applicability. In these ways, IUGG and its associations work to justify public support for research in Earth systems.

The IUGG associations also play a special role in bringing state-of-the-art science to all the countries of the world. This is done primarily through meetings, workshops, and assemblies that are often held in countries that do not normally attract such scientific meetings. IUGG encourage young scientists, particularly those from developing countries, and nurture their participation as scientists and as leaders by subsidizing their participation in symposia and general assemblies.

IUGG has initiated and/or vigorously supported collaborative efforts that have led to highly productive world-wide interdisciplinary research programs, such as the International Geophysical Year (IGY, 1957-58), the Upper Mantle Project (1964-70), the International Hydrological Decade (1965-74), the Geodynamics Project (1972-79), the Global Atmospheric Research Programme (1967-80), World Climate Research Programme (1980-present), International Lithosphere Program (1981-present), Global Geodetic Observing System (2003-present) and others. These programs have set a model for international, interdisciplinary cooperation. The scientific accomplishments of these international programs are too numerous to list, but include discovering the Van Allen radiation belts encircling the Earth, first estimating of the size of Antarctica’s ice mass, confirmation of the Alfred Wegener’s theory of continental drift, understanding seafloor spreading, and developing the new theory of plate tectonics. Even in tense political and economic times (many of the programs were initiated and conducted during the Cold War), scientists from around the world worked together for the betterment of humankind. Representing all geophysical disciplines, IUGG has been, and continues to be, involved in projects and programs related to climate change, global warming, and related environmental impacts. Working under the umbrella of the Inter-governmental Panel on Climate Change (IPCC), IUGG scientists even shared the 2007 Nobel Peace Prize!

IUGG has initiated and supported ICSU initiatives, especially those in which Earth sciences have a role to play. One major contribution was the creation, some 50 years ago, through ICSU, of the World Data Centers and the Federation of Astronomical and Geophysical Data Analysis Services. These are being transformed to the ICSU World Data System, from which the data gathered during major research programs and data products will be available to researchers everywhere. IUGG cooperates with the ICSU GeoUnions, which include IUGG and seven other international scientific unions: the International Astronomical Union, International Geographical Union, International Union for Quaternary Research, International Society for Photogrammetry and Remote Sensing, International Union of Geological Sciences, International Union of Soil Sciences, and the International Union of Radio Science. Joint research topics of these GeoUnions include geoscience data and information, health, natural hazards, and water.

The Role of the United Nations

The establishment of the United Nations and its specialized agencies following World War II broadened the scope of international involvement in scientific programs. Along with ICSU, the World Meteorological Organization (WMO) and U. N. Educational, Scientific, and Cultural Organization (UNESCO), both UN agencies, support the World Climate Research Programme (WCRP). UNESCO also has relevant programs in hydrology (IHP, the International Hydrological Programme) and in geology (IGCP, the International Geosciences Programme). The 2007-2009 International Polar Year, which brought together many nations to investigate Arctic and Antarctic regions, was jointly sponsored by WMO, UNESCO and ICSU.

More recently, the UN International Strategy for Disaster Reduction (UN-ISDR) has become a sponsor of the ICSU research effort on Integrated Research on Disaster Risk (IRDR). IUGG cooperates with UNESCO in the study of natural catastrophes, hydrological and oceanographic research. IUGG also places particular emphasis on the scientific problems of economically less-developed countries by sponsoring activities relevant to their scientific needs (e.g. geosciences in Africa, water resources, health and well-being etc.)

Bridging Between Local and International Efforts

Strengthening cooperation between international, regional and national geophysical and geoscientific unions and societies is one of the principal goals of IUGG activities.

The American Geophysical Union (AGU), established by the National Academy of Sciences as the U.S. National Committee for IUGG in 1919, today has become a distinguished union of individual geoscientists around the world. Several regional geoscience societies also evolved during the last several decades, most prominent being the European Geosciences Union (EGU) and the Asia Oceania Geosciences Society (AOGS). These, and some other national and regional geophysical societies, together with IUGG play a strong part in the international cooperation and promotion of geophysical sciences.

At the same time, there are a lot of overlaps in scientific and science-policy activities of these unions and societies. It is evident that international linkages between IUGG, AGU, EGU, AOGS, and other geophysical societies as well as their linkage with the International Scientific Unions, that comprise the GeoUnions, are going to become more and more important in the 21st century, and cooperation among unions and societies should be strengthened.

The 50th Anniversary of IGY

Several international programs have been associated with IGY's 50th anniversary. These are shining examples of international scientific cooperation between international, regional, and national societies and unions: IPY (2007-2008), International Year of Planet Earth (IYPE, 2007-2009), the International Heliophysical Year (IHY, 2007-2008), and the Electronic Geophysical Year (*e*GY, 2007-2008).

IPY covered two full annual cycles at both poles and sponsored 170 projects involving 60 countries resulting in an overall project budget of about one billion EUR. IYPE, which was proposed by IUGS and UNESCO, endorsed by the UN General Assembly, and enthusiastically supported by IUGG, ILP (the joint IUGG-IUGS international program on lithosphere), AGU, EGU and some other international, regional and national societies, produced an excellent international outreach program ensuring greater and more effective use by society of the knowledge accumulated by the world's Earth scientists. One element of this program was an international meeting of Young Earth Scientists.

The IUGG programs, *e*GY and IHY, were more specific: IHY focused on studies of fundamental heliophysical processes, whereas *e*GY fostered international cooperation in data stewardship. As an example of fruitful cooperation, *e*GY provoked the creation of scientific bodies dealing with data and information and developed links between them: the ICSU Scientific Steering Committee for Information and Data, IUGG Commission on Geophysical Data and Information, AGU Focus Group on Earth and Space Sciences Informatics, and EGU Division on Earth and Space Science Informatics.

The Path Forward: Strengthening Partnerships Between Organizations

Aside from jointly sponsored research endeavors, another way to strengthen international cooperation is to develop joint research meetings. AGU was the first geophysical union to develop scientific meetings jointly with other national and international societies (e.g. Canadian Geophysical Union, national societies in Latin America and Asia, European Geosciences Union, and IUGG Associations). IUGG seeks to implement the policy of joint Scientific Assemblies organized with relevant national and regional groupings.

Joint outreach activity is an important tool of international cooperation. For example, open forums can bring together geoscience unions, policy makers, and representatives of industry and media to discuss how modern science of the Earth system can assist in solving urgent problems of society. In relation to the joint meetings, the unions could develop programs to assist young scientists from the economically less developed countries to attend the joint meetings (the AGU Berkner awards and the host programs of IUGG scientific assemblies are examples of existing international travel grant programs).

Joint policy statements can also foster fruitful cooperation among societies. For example, after the 2004 Indian Ocean great earthquake and tsunami, the IUGG issued a statement and resolution. Based on this resolution and AGU statement on natural hazards, ICSU issued the statement on Science and Natural Hazards. The subsequent implementation of the Indian Ocean Monitoring System is, in part, attributable to the credibility that these resolutions and statements imparted to the process. An upcoming step in international cooperation in natural hazards research will be joint activities as part of the framework of the new ICSU Program on Integrated

Research on Disaster Risk, and the research and outreach programs of the IUGG Commission on Geophysical Risk and Sustainability, the AGU Focus Group on Natural Hazards, and the EGU Division on Natural Hazards.

Knowledge and data on the Earth system gained during international research cooperation provide the information necessary for the discovery and responsible use of natural resources, sustainable management of the environment, and reducing the impact of natural hazards, Further, through international cooperation, scientists can satisfy the world's curiosity about the Earth's natural environment and the consequences of human activities.

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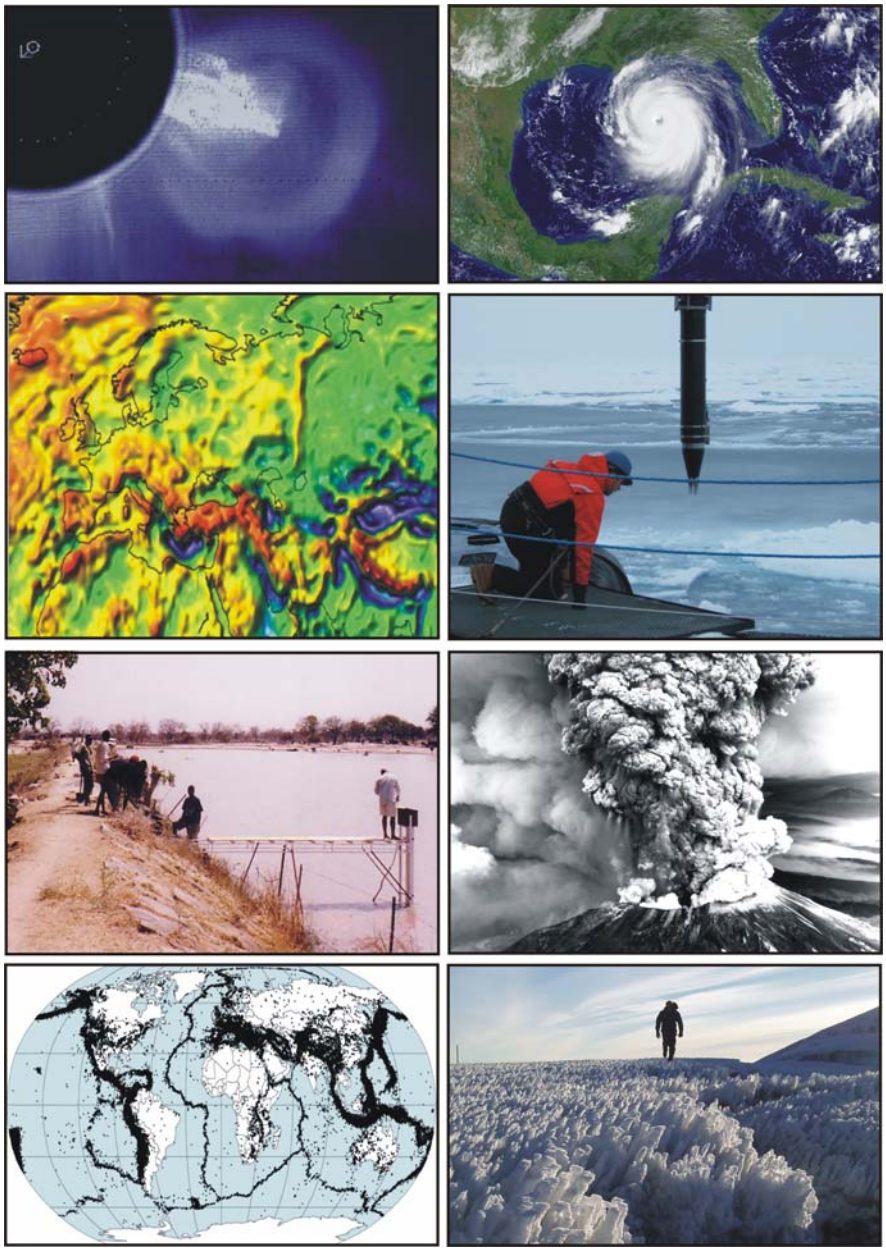

Figure 1. International cooperation in all fields of Earth and space sciences is an essential component of modern research and societal advancement. These fields include (left to right, top to bottom) solar physics and space weather, represented by a coronal mass ejection (image courtesy of National Center for Atmospheric Research High Altitude Observatory, Boulder, Colorado); atmospheric sciences, represented by a picture of 2005 Hurricane Katrina (courtesy of National Oceanic and Atmospheric Administration); geodesy, represented by gravity field measurements from the Gravity Recovery and Climate Experiment (GRACE) mission combined with terrestrial data (model EIGEN-CG03C, courtesy of C. Reigber, GeoForschungsZentrum, Potsdam, Germany); ocean sciences, seen here in an image of a scientist collecting measurements of salinity, temperature, and velocity in the oceanic water column using a microstructure instrument (image courtesy of J. Rodhe, University of Gothenburg, Gothenburg, Sweden); hydrology, seen here in a picture of researchers collecting water level measurements of a reservoir constructed to store seasonal rainfall for domestic use, animal watering, and small-scale irrigation in Zimbabwe (courtesy of P. Hubert, International Association of Hydrological Sciences); volcanology, seen here through the eruption of Mount St. Helens, 18 May 1980 (courtesy of U.S. Geological Survey); seismology, represented by a map of global earthquake epicenters between 1963 and 1998; and cryospheric studies, seen here in an image of "nieve penitentes" on top of Mount Kilimanjaro (courtesy of G. Kaiser, University of Innsbruck, Innsbruck, Austria).