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*Review article*

# A. B. Dobrowolski – the first cryospheric scientist – and the subsequent development of cryospheric science

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**Abstract.** The origin of the term "cryosphere" has been traced to the Polish scientist A. B. Dobrowolski in his 1923 book on "The Natural History of Ice" written in Polish. This note commemorates his little recognized contribution to the science, outside of his native country, and summarizes the recent organization of cryospheric research.

## 1 A. B. Dobrowolski

Antoni Bolesław Dobrowolski (1872–1954) was born into an indigent family, but with a high regard for education as a valued and proper way of life. He started to be self-dependent at the age of 12 when he became a high school student in Warsaw. His minimal income was mostly from teaching younger pupils with occasional support from an older brother. Dobrowolski was involved in an illegal student political organization claiming independence for Poland from the Russian Empire. After his matriculation exams he was arrested and sentenced to thee years' imprisonment. As a political prisoner he was transported to the Caucasus but after two years he escaped from there (Dobrowolski, 1958). Following his escape from Russia he studied physics and biological sciences in Switzerland and Belgium.

He applied to be a member of the Belgian Antarctic Expedition on the ship *Belgica* turning up in Antwerp in August 1897 several days before their departure. The Polish scientist Dr. Henryk Arctowski, who was the leader of the scientific team of the expedition and mentor of his younger colleague, was unable to persuade the expedition's leader Adrien de Gerlache de Gomery to take Dobrowolski on the expedition. Very fortunately for him, however, the wheel of the *Belgica*'s steam engine was broken and the ship went to Ostend for repair. Two members of the expedition quit at this time and Dobrowolski was contracted as a simple sailor. Later, in the middle of the cruise and during overwintering in the Antarctic, he became a formal member of the scientific group (Dobrowolski, 1958). He was employed as a meteorological technician during the multinational expedition, 1897–1899 (Machowski, 1998). Subsequently, after returning from the expedition, Dobrowolski received a two-year scholarship in Belgium to analyze the results of his studies.

Dr. Henryk Arctowski and A. B. Dobrowolski conducted the first year-round meteorological and oceanographic observations off Antarctica, in the Bellingshausen Sea where the ship was beset by ice. The expedition reached 71.6° S. Dobrowolski also carried out studies of ice crystallography, and light phenomena within ice clouds, that laid the foundations for his book. He also carried out observations on snow crystallography, snow dunes and types of snow cover in Sweden in the years 1915–1917. Such additional observations and data with photographs were added to his monograph.

He returned to Warsaw in 1907 after the declaration of amnesty for political refugees by the Russian Emperor Nicolay the 2nd. Dobrowolski was active in many fields promoting the development of the State Institute of Meteorology in the independent Poland after the First World War, creating the Polish Geophysical Society, and being patron of Polish activity during the Second International Polar Year (1932–1933) and Arctic expeditions during subsequent years.

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Dobrowolski apparently wrote the book *Historia naturalna lodu* (The natural history of ice, in Polish) in 1916, but it was not published until 1923.

It has a summary of the chapter contents in French. It fills 940 pages and represents a comprehensive account of all forms of snow and ice – in the atmosphere, on land and water, and in the ground. The topics of the 14 chapters are: conditions for the freezing of water; conditions for the freezing of water vapor; general conditions in the growth of atmospheric ice; crystallography of ice; crystallization of water vapor in clouds and fog; crystallization of water vapor at the surface of solid bodies; freezing of droplets; freezing of calm water; freezing of turbulent water; freezing of soil water; physical properties of snow cover; snow cover description; glacier structure; and glacier movement. Each chapter has an extensive bibliography.

## 2 The cryosphere

At the beginning of his book, Dobrowolski (1923, p. 2) defines the cryosphere – from the Greek word krios meaning icy cold – as a zone extending from the upper part of the troposphere, where ice crystals occur in clouds, to the base of the permafrost (Jania, 1997, p. 25). He introduced the concept of the cryosphere as a special part of the lithosphere, closely connected to the hydrosphere and the atmosphere. He also proposed the recognition of cryology as a separate science dealing with the solid phase of water in all its aspects, of whatever origin, and recommended that it form a part of physical geography.

The American J. E. Church and Briton G. Seligman (founder of the British Glaciological Society), who were both snow scientists, distinguished between "snow" and "ice", neglecting Dobrowolski's idea of homogeneity in composition of all natural forms of ice (including snow crystals). At the Sixth General Assembly of the International Union of Geophysics and Geodetics (IUGG) held in Edinburgh in 1936, there was a joint symposium of the Commissions of Snow and Glaciers. The symposium had 80 papers on all aspects of glaciology (IAHS, 1938). Dobrowolski was Vice-President of the Glacier Commission at that time. Church and Seligman both presented papers and were involved in discussions on the topic of terminology during the conference. However, Dobrowolski's ideas (Dobrowolski, 1938) were not accepted by the majority of the participants (Radok, 1997). In part this may have been because Dobrowolski, although an excellent writer, was a poor speaker (Alfred Jahn, personal communication, 1995) and was not communicating in his native language; yet he was fluent in French, German, English and Russian. Also, Jones (2008) notes that at the time, the IUGG Associations were financially constrained with insufficient funds to carry out their mandates. Another factor was the prevailing view among members of the International Association of Scientific Hydrology (IASH) that glaciology was a sub-discipline of hydrology.

Dobrowolski was deeply disappointed by the neglect of his idea of the unity of all kind of ice in nature and the need for the formation of one international scientific organization for stimulating the development of cryology. In his memoirs, written in 1947, but published finally after his death (Dobrowolski, 1958, p. 322–323) he complained about the changes in names of the Commission of Snow and Ice and the article by Seligman (1947, p. 33) in the first issue of the *Journal of Glaciology* on the term "cryology". He writes "at the last 7th General Assembly of the International Union of Geodesy and Geophysics in Washington (D.C.), in September 1939, at which I could not be present, and which was not successful for the reason of the beginning of the Second World War, they decided to change the name to the less appropriate: 'Commission on Snow and Glaciers', excluding – beside rime, hail, and frozen rain – ice cover of waters with anchor ice and slush, together with frozen ground, and only for stressing the underlining of the definite merger of two previous Commissions. Finally at the end of last year (1946), mentioned already above, the President of the British Association for the Study of Snow and Ice changed the name of this society to 'British Glaciological Society', obviously inappropriate. In such a name two motivations are visible: first – acceptance, despite the former previous contradiction of my request of one adjective – for studies of all aspects of ice, the acceptance of such study as a separate scientific discipline; second – investigations *par force* of a different name than 'cryology'. It is strange, but that is it. Publication of the Society *Journal of Glaciology* in its first issue from January 1947 placed – beside a very 'warm' editorial note about myself – a real attack on this Greek word as an 'unwelcome newcomer' to which he [Seligman] and his fellow scientists purportedly feel 'abhorrence'. As an illustration of such feelings, he quoted (beside repeated arguments) only two: the word *cryology* is funny for Anglo-Saxon, because *cry* in English means outcry. Probably he did not know that Anglo-Saxon physical chemists are using it in generally accepted terms *cryoscope*, *cryohydrate* . . . "

In fact, in his last sentence, Seligman (1947) wrote: "It is to be hoped that 'cryology', so far as the scientific study of ice is concerned, will never be heard of again". Nevertheless, in the Soviet Union, the term cryology [kriologiya in Russian] was adopted from the Dobrowolski's monograph and the term geocryology – derived from the Russian word geokriologiya – was already in wide use. Sumgin et al. (1940) wrote a textbook with that title and since the 1970s the term has been widely used by the permafrost community in the western world to refer to the study of perennially and seasonally frozen ground.

It is to be noted that Seligman did not address use of the term cryosphere.The term cryosphere largely languished, despite Dobrowolski's (1951) further written efforts, until it was picked up by Shumskii (1955) in the Soviet Union and

by Reinwarth and Stäblein (1972) in Germany. In the 1980s in North America, Bentley (1984), Untersteiner (1984) and Barry (1985) utilized the term and soon it came into general use for all forms of snow and ice on land, water, and under the ground. The atmospheric component included by Dobrowolski and Shumskii is today not generally considered in treatments of the cryosphere, except for snowfall and other forms of solid precipitation. A text on the global cryosphere is currently in press (Barry and Gan, 2011).

## 3 The subsequent evolution of cryospheric science and the organization of cryospheric research

It took more than 50 yr after Dobrowolski published his text on the cryosphere for a unified approach to evolve. During the 1970s studies of the cryosphere were transformed from in situ fieldwork on a local scale to basin-scale investigations of the spatial extent and characteristics of the main components of the cryosphere – snow cover, glaciers, ice sheets and sea ice. This evolution depended heavily on the advent of satellite remote sensing using optical sensors on NOAA platforms from 1966 and Landsat from 1972. In Hall and Martinec's (1985) book on remote sensing of snow and ice the emphasis is still on basins and regional scale features, but passive microwave data allowed the first hemispheric, all-weather, year-round views of polar sea ice (Zwally and Gloersen, 1977) and this hemispheric scale approach was later extended to all cryospheric components. Global remote sensing involving all spectral wavelengths is now a mainstay of cryospheric research especially in polar and mountain regions where access is difficult (Thomas, 1991).

A separate innovation in the 1970s was the development of general circulation models (GCMs) of the atmosphere and their early application to studies of the climatic conditions at the Last Glacial Maximum (Williams et al., 1974) and to the cryospheric impacts of carbon dioxide-induced global warming (Parkinson and Kellogg, 1979). In the 1980s and 1990s second and third generation coupled atmosphere-ocean GCMs began to incorporate elements of the cryosphere that interacted with the climate system (for example, by ice-albedo feedbacks). The development of land surface schemes played an important role in this evolution and these are continually being enhanced for snow cover, land ice and permafrost processes as stand- alone models or components of GCMs.

With the advent of NASA's Earth Observing System program in the 1980s, several hemispheric and interdisciplinary studies of snow and ice were started. In Canada, Barry Goodison led the formation of the CRYSYS (Cryosphere System in Canada) research project in 1988. This activity subsequently led to the establishment of the Canadian Cryospheric Information Network (CCIN) (Piwowar et al., 2002), modeled in part on the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado. The latter was designated by the National Oceanic and Atmospheric Administration (NOAA) in the United States in 1982, but its role was greatly expanded in the early 1990s when NASA established the Distributed Active Archive Center (DAAC) for snow and ice data. Global data sets for all individual cryospheric variables are prepared and maintained (http://nsidc.org). The combination of funded research and the establishment of data centers, which distribute (primarily) remote sensing data in both Canada and the United States, spurred heightened awareness of global and hemispheric cryospheric processes. At present the two combined snow cover and sea ice products are the Near-real-time Ice and Snow Extent (NISE) which provides daily, global near-real-time maps of sea ice concentrations and snow extent since 1995 (http://nsidc.org/data/nise1.html) and the Interactive Multisensor Snow and Ice Mapping System (IMS) for the Northern Hemisphere of the National Oceanic and Atmospheric Administration (NOAA) since 1997 (http://www.natice.noaa.gov/ims/).

The convergence of global climate models, remote sensing data, and science community interest in the cryosphere is reflected in such groups as the World Climate Research Program (WCRP) which identified gaps in our knowledge of cryospheric processes operating in the climate system and summarized the various options for the organization of cryospheric studies within WCRP (Barry, 1998). The Joint Scientific Committee (JSC) of WCRP endorsed the idea of a broad program on Climate and Cryosphere (CliC) within WCRP in 1998. As a first step, a science and coordination plan was prepared for CliC, which was established in March 2000 (Barry, 1999; Allison et al., 2001). Its 15-yr program and ongoing activities are described at: http://clic.npolar.no. At the same time, within the Earth Observing System program of NASA, a science implementation plan was developed that included cryospheric systems (Goodison et al., 1999).

Further movement towards a more integrated research approach to the cryosphere is evidenced by changes in national and international scientific organizations. The Snow, Ice and Permafrost Technical Committee of the American Geophysical Union (AGU) was renamed the Cryosphere Focus Group in 2002. The number of submitted abstracts increased from 120 in 2002 to 687 in 2010 and 1015 AGU members identified this focus group as their primary affiliation. Cryospheric science sessions were organized at the EGS-AGU-EUG Joint Assembly in Nice, France in April, 2003 and the following year the new Division of Cryospheric Sciences organized sessions at the First General Assembly of the European Geophysical Union.

Through the initiative of Gerry Jones, President of the International Commission of Snow and Ice (ICSI) of the International Association of Hydrologic Sciences (IAHS) during 2001–2005, a three-member panel (Roger Barry, Georg Kaser and Wilfried Haeberli) prepared a statement on the case for establishing an International Association for Cryospheric Sciences (IACS). The International Union of

Geophysics and Geodetics (IUGG) approved the designation of an IUGG Commission for the Cryospheric Sciences (UCCS) in Boulder in September 2004, and at the subsequent General Assembly in Perugia, Italy in July 2008, the International Association of Cryospheric Sciences (http://www.cryosphericsciences.org) became the eighth association of the IUGG, with Georg Kaser of Austria as its first President. It was the first new Association to be formed in over 80 yr. A detailed account of the history of the foundation of the IACS is provided by Jones (2008). The establishment of the IACS finally recognizes the importance of the cryosphere in the study of earth system science – a testimony to Dobrowolski's foresight.

## 4 Concluding remarks

The term cryosphere has a long history that is finally being recognized internationally. The Polish scientist A.B. Dobrowolski can be identified as the "father" of the concept. The neglect of the term between 1923 and 1955 can be attributed to scientific personalities and world history (the Second World War). In the 1990s the World Climate Research Program and the IAHS International Commission on Snow and Ice played important roles in promulgating the term. The term cryology, proposed by Dobrolwolski has been less widely accepted as the science of snow and ice, because "glaciology" is so defined. Moreover, cryology is also used to refer to the science of refrigeration. Nevertheless, the term geocryology is widely accepted by the permafrost community. In light of the decisions of distinguished international scientific bodies just before and after the Second World War, interpersonal disagreements of eminent scientists and their affection for traditional terms, and organizations created by them, it has taken nearly a century for the term cryosphere to be fully accepted in international scientific language.

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## References

Allison, I., Barry, R. G., and Goodison, B. (Eds.): Climate and cryosphere (CliC) project science and co-ordination plan, Version 1, WCRP-114, WMO/TD No. 1053, Geneva, World Meteorological Organization, 76 pp., 2001.

Barry, R. G.: The cryosphere and climate change, in: Detecting the climatic effects of increasing carbon dioxide, edited by: MacCracken, M. C. and Luther, F. M., DOE/ER 0235, Washington DC, US Dept of Energy, 109–148, 1985.

Barry, R. G.: Organization of internationally co-ordinated research into cryosphere and climate, Proceedings of a meeting of experts on cryosphere and climate, Geneva, World Climate Research Programme, WCRP-102, WMO/TD No. 867, 10 pp. + Appendices, 1998.

Barry, R. G. (Ed.): Organization of internationally co-ordinated research into cryosphere and climate, Summary report of the WCRP (JSC/ACSYS) Climate and Cryosphere Task Group, Geneva, WCRP Informal Report No. 4/99, 27 pp., 1999.

Barry, R. G. and Gan, T. Y.: The global cryosphere – past, present, and future, Cambridge, Cambridge University Press, in press, 2011.

Bentley, C. R.: Some aspects of the cryosphere and its role in climatic change, in: Climate processes and climate sensitivity, edited by: Hansen, J. and.Takahashi, T., Geophysical Monograph, 29, 207–220, 1984.

Dobrowolski, A. B.: Historia naturalna lodu (The natural history of ice), Warszawa: Kasa Pomocy im. Dr. J. Mianowskiego, 940 pp., 1923 (in Polish with French summary, 926–940).

Dobrowolski, A. B.: Sur le problème de la réalisation d'une organisation cryologique internationale, Transactions of the International Commissions of Snow and of Glaciers, Sixth General Assembly, Edinburgh, 1936, Latvia, Riga, 65–75, 1938.

Dobrowolski, A. B.: Commission, ou bien Association? 'Des Neiges et des Glaces', 'de Glaciologie' ou bien 'de Cryologie'?, Internat. Assoc. Sci. Hydrol. Bull., 32, 142–144, 1951.

Dobrowolski, A. B.: Mój życiorys naukowy [My scientific life], Zakład Narodowy Imienia Ossolińskich – Wydawnictwo, Wrocław, 418 pp., 1958 (in Polish).

Goodison, B. E., Brown, R. D., and Crane, R. G.: Cryospheric systems, EOS Science Plan, Washington, DC, NASA, 261–307, 1999.

Hall, D. K. and Martinec, J.: Remote sensing of snow and ice, London, Chapman and Hall, 189 pp., 1985.

International Association of Scientific Hydrology: Transactions of the International Commissions of Snow and of Glaciers, Sixth General Assembly, Edinburgh, 1936, Latvia, Riga, 822 pp., 1938.

Jania, J.: Glacjologia [Glaciology], Warsawa: Wydawnictwo Naukowe, PWN, 359 pp., 1997 (in Polish).

Jones, H. G.: From Commission to Association: the transition of the International Commission on Snow and Ice (ICSI) to the International Association of Cryospheric Sciences (IACS), Ann. Glaciol., 48, 1–5, 2008.

Machowski, J.: Contribution of H. Arctowski and A. B. Dobrowolski to the Antarctic Expedition of Belgica (1897–1899), Polish Polar Res., 19, 15–30, 1998.

Parkinson, C. L. and Kellogg, W. W.: Arctic sea ice decay simulated in a $CO_2$-induced temperature rise, Clim. Change, 2, 149–162, 1979.

Piwowar, J. M., LeDrew, E. F., Brown, R., Goodison, B. E., Polanski, M., and Hirose, T.: The Canadian Cryospheric Information Network: Facilitating access to sea ice, lake ice, snow cover, permafrost, and glacier data, Geoscience and Remote Sensing Symposium, 2002, IGARSS '02, IEEE International, 1, 214–216, 2002.

Radok, U.: The International Commission on Snow and Ice (ICSI) and its precursors, 1894–1994, Hydrol. Sci. J., 42(2), 131–140, 1997.

Reinwarth, 0. and Stäblein, G.: Die Kryosphäre, das Eis der Erde und seine Untersuchung, Würzburg, Würzburger Geographische Arbeiten, 36, 71 pp., 1972.

Seligman, G.: "Cryology", J. Glaciol., 1(1), p. 35, 1947.

Shumskii, P. A.: Principles of structural glaciology, Translated by D. Kraus, 1964, New York, Dover Publications Inc., 497 pp., 1955 (in Russian).

Sumgin, M. I., Kachurin, S. P., Tolstukhin, N. I., and Tumel', V. F.: General Geocryology, Moscow, Russia, Academy of Science, 1940 (in Russian).

Thomas, R. H.: Polar research from satellites, Washington, DC, Joint Oceanographic Institutions Inc., 1991.

Untersteiner, N.: The cryosphere, in: The global climate, edited by: Houghton, J. T., Cambridge, UK, Cambridge University Press, 121–140, 1984.

Williams, J., Barry, R. G., and Washington Jr., W. M.: Simulation of the atmospheric circulation using the NCAR Global Circulation Model with Ice Age boundary conditions, J. Appl. Met., 13, 305–317, 1974.

Zwally, H. J. and Gloersen, P.: Passive microwave images of the polar regions and research applications, Polar Record, 18, 431–450, 1977.