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Imagining climates past, present and future: Soviet contributions to the science of anthropogenic climate change, 1953–1991

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A B S T R A C T

This paper builds on recent work in the critical geographical literature concerned with advancing a more nuanced engagement with climate change science and linked knowledges. The main aim of this paper is to provide insight into the character of Soviet climate science, and reflect on the contribution of Soviet scientists to the international debate concerning anthropogenic climate change and associated forecasting as it developed from the late 1950s through to the first report of the IPCC in 1990. Such a focus is significant for a number of reasons. First, Soviet contributions are given short shrift in general reviews concerning the development of the basic science underpinning anthropogenic climate change, emerging as a subdued 'other' despite their relative importance during this period at the international level. Second, the Soviet contingent also played an influential role in the formation of the IPCC as well as the development of associated debates concerning the establishment of future climate change scenarios. Third, the early IPCC process resulted in the relative marginalisation of Soviet scientific input framed by debates over the most effective way to determine future climate change scenarios. The paper examines the significance of Soviet science for the evolving climate change debate on the international stage, and the related involvement of a handful of Soviet scientists in the activities of international bodies such as the World Meteorological Organisation (WMO). It also examines the role of Soviet scientists in the consolidation of a natural science conceptualisation of anthropogenic climate change during the late 1980s. It is shown how the Soviet contingent came to place an emphasis on the use of palaeoclimatic analogues in order to predict future climates, albeit whilst recognising the value of the computer modelling approach favoured by many Western climatologists. Nevertheless, this preference for an analogue approach and resultant debates surfaced strongly during the early work of the IPCC. The robust advancement of General Circulation Models (GCMs) as the prime forecasting technique within Working Group I resulted in the effective side-lining of the Soviet contingent during the process of finalising the first IPCC report in 1990.

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Historical accounts of the science underpinning notions of anthropogenic climate change trace a path from the circumscribed work of nineteenth-century North American and European physical scientists, through to the later applied and conceptual work of individuals such as Guy Stewart Callendar and Gilbert Plass, and the internationalisation of the climate change issue by various bodies including the World Meteorological Organisation (WMO). An associated tendency to focus on 'signal moments' such as the publication of the Keeling Curve, contributes to an underlying narrative characterised by a growing awareness of the role of carbon dioxide (CO_2) and other anthropogenic greenhouse gases in the functioning of global geophysical systems, and a strengthening emphasis on the use of climate models in order to anticipate future climate trends.[1] This narrative also draws attention to the convoluted nature of scientific progress, the influence of military and state patronage, and the essential importance of international cooperation for the furthering

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[1] R. Hamblyn, The whistleblower and the canary: rhetorical constructions of climate change, *Journal of Historical Geography* 35 (2009) 224; S. Boehmer-Christiansen, Science policy, the IPCC and the Climate Convention: the codification of a global research agenda, *Energy and Environment* 4 (1993) 375–377; A.D. Hecht and D. Tirpak, Framework agreement on climate change: a scientific and policy history, *Climatic Change* 29 (1995) 371–402; J.R. Fleming, *Historical Perspectives on Climate Change*, Oxford, 1998, 107–128; S.R. Weart, *The Discovery of Global Warming*, Cambridge MA, 2003.

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of insight into anthropogenic climate change post-1945.

Geographers have been at the forefront of exploring the limitations of such historical constructions of the climate change debate, placing an emphasis on the need to engage with the multiple knowledges involved in comprehending climatic processes, as well as the significance of different scales of analysis for interpreting past, present and future climates.[2] Furthermore, this critique has been joined by overlapping debate concerning the hierarchy of science evident in key organisations such as the Intergovernmental Panel on Climate Change (IPCC), and the tendency for certain branches of the physical sciences to dominate policy responses, allied to the relative marginalisation of the social sciences and humanities.[3] Drawing inspiration from both areas of discussion, this paper explores the place and role of Soviet science in the broader development of climate change science during the Cold War period.

Soviet climate science is given short shrift in the general historiographical work noted above, emerging as a somewhat marginalised 'other' in the context of the Cold War. The main aim of this paper is to offer a detailed synopsis of the character of Soviet climate science, and to reflect on the hitherto largely overlooked contribution of Soviet scientists to the international debate concerning anthropogenic climate change as it developed from the late 1950s through to the first report of the IPCC in 1990. It should be noted that the Soviet Union also developed an agenda concerning climate change with other socialist countries; however, in view of space constraints, the focus of this paper is on Soviet engagement with the broader international context.[4] A purposeful evaluation of the Soviet Union's efforts in this area as they developed post-WWII promises a more nuanced understanding of the history of climate change science, one that recognises the existence of marginalised layers of understanding within the broader international discourse of anthropogenic climate change. Linked to this, it also assists in opening up key areas of debate concerning the construction of future climate change scenarios during the formative early years of the IPCC process. Broadly speaking, Soviet scientists made significant contributions to the natural science view of anthropogenic climate change that emerged so strongly post-1945, and were responsible for some of the earliest forays into predicting climate futures. Thus, they form a key part of the consolidation of a natural science approach to climate change that crystallised during the late 1980s.[5] At the same time, they accentuated particular approaches to the issue, some of which would bring them into conflict with competing accounts within the international scientific community as will be discussed below.

Soviet scientific commitment to the climate change issue was characterised by a number of broad trends during 1945–1991. First, innovative advances were made with respect to physical and quantitative climatology, and particularly the functioning of the heat-water balance at the Earth's surface, which provided a basis from which to deepen understandings of the global climate system more generally. Second, certain Soviet climatologists and cognate scientists engaged progressively with the notion of society's growing influence on the climate system from the early 1960s onwards, integrating such understanding with more developed concepts of the global physical system, and this included early work on future climate predictions.[6] Third, Soviet scientists were influential participants in the evolving international agenda, taking an active role in initiatives such as the formative International Geophysical Year event as well as the activities of the WMO and IPCC.[7] Fourth, Soviet work at the international level concerning climate change forecasts tended to be dominated by a relatively small group of scientists who became increasingly marginalised by the Western consensus around climate change futures that emerged during the foundational work of the IPCC in the late 1980s.

In order to explore aspects of these general trends in more detail and focus the analysis, the paper is structured around three main sections, which in turn draw heavily from the work and activities of four key protagonists. These are: climatologist M.I. Budyko (1920–2001), geophysicist E.K. Fedorov (1910–1981), atmospheric physicist K.Ya. Kondrat'ev (1920–2006) and geophysicist Yu.A. Izrael' (1930–2014). Collectively these four scientists produced a large body of work devoted to climate change as well as broader global environmental concerns. Furthermore, they were all highly visible on the international scene and played significant roles in the WMO and related initiatives. It should be borne in mind that the dominance of the protagonists highlighted, particularly on the international stage, drew attention away from the more involved domestic debate in this area. Space precludes a more detailed examination of this domestic debate. Nevertheless, the subsequent analysis does provide insight into some key trends characterising Soviet engagement with the climate change issue post-1945.

The opening section places the paper's empirical findings within the context of recent work related to the environmental history of the Cold War period. The subsequent section moves on to assess Soviet thinking with respect to climate change post-1945 in order to provide a framework for assessing Soviet engagement with the corresponding international agenda. The final section examines the nature of Soviet involvement in international initiatives of significance for the development of climate change science. It does this via a focus on three substantive areas of activity. First, Soviet engagement with the Nuclear Winter debate that emerged strongly during the 1980s is examined in view of this debate's connection with future efforts to model climate processes at the global scale. Second, Soviet interaction with US climate scientists as part of broader initiatives around environmental concerns from the 1970s onwards is explored. The final area of focus offers an insight into Soviet interaction with the WMO and the flurry of activity underpinning the publication of the IPCC's First Assessment Report in 1990. Soviet engagement with the IPCC process is particularly significant in view of this organisation's subsequent emergence as a key consensus-builder with respect to climate science. The empirical heart of the paper falls between 1953 and 1990, sandwiched between the death of Stalin and the publication of the noted IPCC report.

[2] C. Brace and H. Geoghegan, Human geographies of climate change: landscape, temporality, and lay knowledges, *Progress in Human Geography* 35 (2010) 284–302; M.T. Bravo, Voices from the sea ice: the reception of climate impact narratives, *Journal of Historical Geography* 35 (2009) 256–278; S. Daniels and G.H. Endfield, Narratives of climate change: introduction, *Journal of Historical Geography* 35 (2009) 215–222; D.W. Gamble, D. Campbell, T.L. Allen, D. Barker, S. Curtis, D. McGregor and J. Popke, Climate change, drought, and Jamaican agriculture: local knowledge and the climate record, *Annals of the Association of American Geographers* 100 (2010) 880–893.

[3] For example, M. Hulme, Geographical work at the boundaries of climate change, *Transactions of the Institute of British Geographers* 33 (2008) 5–11; M. Hulme and M. Mahony, Climate change: what do we know about the IPCC?, *Progress in Physical Geography* 34 (2010) 705–718; D.M. Liverman, Conventions of climate change: constructions of danger and the dispossession of the atmosphere, *Journal of Historical Geography* 35 (2009) 285–288.

[4] K.M. Lugina, Sotrudnichestvo sotsialisticheskikh stran v oblasti issledovaniya izmeneniya klimata, *Meteorologiya i Gidrologiya* 4 (1988) 134–136.

[5] M. Hulme, Reducing the future to climate: a story of climate determinism and reductionism, *Osiris* 26 (2011) 245–266.

[6] See J.D. Oldfield, Mikhail Budyko's (1920–2001) contributions to global climate science: from heat balances to climate change and global ecology, *WIREs Climate Change* 7 (2016) 682–692.

[7] V.V. Belousov and V.A. Troitskaya, Mezhdunarodnyi geofizicheskii god, *Vestnik Akademii Nauk SSSR* 7 (1957) 3–7; Akademii nauk, Uchastie sovetskikh uchenykh vo vsemirnoi programme issledovanii klimate, *Vestnik Rossiiskoi Akademii Nauk* 3 (1987) 106–117.

Climate science and environmental histories of the Cold War

There is a large, multi-disciplinary literature on the environmental characteristics of both Western and Soviet societies post-1945, capturing the emergence of a substantive environmental movement in the West, a burgeoning international infrastructure for addressing environmental concerns, and a general critique of the Soviet system's environmental credentials.[8] More recently, there has been growing interest in a purposeful environmental history of the Cold War period, which draws attention to the Cold War's role in influencing human understanding and utilisation of the biosphere as well as its impact on the physical state of Earth at a range of scales.[9]

A strong thread running through related scholarship concerns the influence of the Cold War on the physical sciences, which in turn builds on the extensive literature examining the links between science, the military and the state during this period.[10] Much of this scholarship has been directed towards the physical sciences in the West, although there is an emerging literature concerning the Soviet experience.[11] The noted influence of the military in shaping the development of the physical sciences was driven by a need to understand the physical parameters of the Earth's geophysical systems to facilitate communication and monitoring activities at a global scale, and to understand the flight of rockets and related weaponry as well as the consequences of nuclear pollution.[12] What emerges from this body of work is how little was known about global geophysical processes during the early post-war years. The reasons for this can be related to the predominance of a nation-state system, an embryonic intergovernmental infrastructure, inadequate monitoring and data collection networks with limited historicity, and the geopolitics of Cold War knowledge circulation.[13] As James Ryan and Simon Naylor suggest, exploration activities remained a key feature of the twentieth century, with attention devoted to the polar regions in addition to the atmosphere and oceans.[14] The Third International Polar Year, which morphed into the International Geophysical Year (1957–1958), emerges as a key event within much of this scholarship, providing the impetus for large-scale scientific collaboration across the ideological divide.[15] The IGY also gave a significant boost to the use of rocketry and related technologies in exploring the more inaccessible regions of the earth's geophysical environment; an area of activity epitomised by the Soviet Union's success in launching Sputnik 1 during October 1957.[16] The need for international scientific collaboration would intensify during the post-IGY period, driving the formation of further large-scale scientific initiatives as well as the programmes of UN-sponsored organisations.[17]

Climate science and the Cold War

Spencer Weart notes the relatively low standing of climatology as a science during the early post-war years and underlines the fact that at this time much of the funding linked to climate change science was indirect and an outcome of an instrumental desire to know how the Earth's physical systems functioned.[18] Interest in the production of detailed, day-to-day weather data also gained traction during this period. Effective weather forecasting challenged national boundaries as well as ideological ones. It was required to assist economic planning, shipping activities, air flights, and a host of other socio-economic activities. In time, systematic weather data would also provide effective input for climate modelling. The twin concerns of short-term weather forecasting and climate system understanding encouraged the formation of a more effective global system of weather data generation grounded on advances in computing technology. The linked history of climate modelling is dominated by US and European scientists, although Soviet academics such as Budyko produced influential semi-empirical climate models during this period.[19] Furthermore, the Soviet Union was not short of skilled climate modellers, building on the country's strong traditions in mathematics, physics and related fields, and there was evidence of a robust exchange of expertise between East and West in this area.[20] Nevertheless, explicit mention is made in many Western accounts of the relative backwardness of Soviet computing technology, thus helping to retard their development of large-scale computer modelling systems such

[8] For example, S. Brain, The environmental history of Russia, in: *Oxford Research Encyclopedia of Environmental Science*, 2016, https://doi.org/10.1093/acrefore/9780199389414.013.355; J.S. Dryzek and D. Schlosberg (Eds), *The Environmental Politics Reader: Debating the Earth*, Oxford, 2005; P. Josephson, N. Dronin, A. Cherp, R. Mnatsakanian, D. Efremenko and V. Larin, *An Environmental History of Russia*, Cambridge, 2013.

[9] J.R. McNeill and C.R. Unger, The big picture, in: J.R. McNeill and C.R. Unger (Eds), *Environmental Histories of the Cold War*, Cambridge, 2010, 3; see also R.E. Doel, R.M. Friedman, J. Lajus, S. Sörlin and U. Wråkberg, Strategic Arctic science: national interests in building natural knowledge—interwar era through the Cold War, *Journal of Historical Geography* 44 (2014) 60–80; J.D. Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism*, Oxford, 2013.

[10] For example, R.E. Doel, Constituting the postwar earth sciences: the military's influence on the environmental sciences in the USA after 1945, *Social Studies of Science* 33 (2003) 635–666; N. Oreskes and J. Krige, *Science and Technology in the Global Cold War*, Cambridge MA, 2014.

[11] For example, E. Aronova, Environmental monitoring in the making: from surveying nature's resources to monitoring nature's change, *Historical Social Research/Historische Sozialforschung* 40 (2015) 222–245; M. Elie, Formulating the global environment: Soviet soil scientists and the international desertification discussion, 1968–91, *The Slavonic and East European Review* 93 (2015) 181–204; E. Rindzeviciute, *The Power of Systems: How Policy Sciences Opened Up the Cold War World*, Ithaca NY, 2016.

[12] P.N. Edwards, Meteorology as infrastructural globalism, *Osiris* 21 (2006) 229–250; K. Dodds, Assault on the unknown: geopolitics, Antarctic science and the International Geophysical Year, 1957-58, in: S. Naylor and J.R. Ryan (Eds), *New Spaces of Exploration: Geographies of Discovery in the Twentieth Century*, London, 2009, 148–172; S. Turchetti and P. Roberts (Eds), *The Surveillance Imperative: Geosciences During the Cold War and Beyond*, New York, 2014; J.R. Fleming, *Fixing the Sky: The Checkered History of Weather and Climate Modification*, New York, 2010.

[13] At the same time, M. Mahony, in his paper 'For an empire of 'all types of climate': meteorology as an imperial science' *Journal of Historical Geography* 51 (2016) 29–39, notes how the British Empire embodied 'all types of climate', and thus its meteorological services acquired understanding of a range of climatic conditions across the globe. The extent of the Russian Empire provided similar opportunities for Russian scientists. Nevertheless, understanding of global physical systems remained relatively weak for the reasons highlighted. The author is grateful to one of the reviewers for highlighting this point.

[14] J.R. Ryan and S. Naylor, Exploration in the twentieth century, in: Naylor and Ryan (Eds), *New Spaces of Exploration*, 11–22.

[15] C. Collis and K. Dodds, Assault on the unknown: the historical and political geographies of the International Geophysical Year (1957–8), *Journal of Historical Geography* 34 (2008) 555–573; W. Sullivan, *Assault on the Unknown: The International Geophysical Year*, London, 1961; Yu.D. Bulanzhe, Mezhdunarodnyi geofizicheskii god, *Vestnik Akademii Nauk SSSR* 1 (1956) 3–8.

[16] L.V. Berkner (Ed.), *Annals of the International Geophysical Year. Rockets and Satellites Volume 6, Parts I-V*, London, 1958, 1; E. Fedorov, Velikaya pobeda tvorcheskoi mysli, *Pravda*, 6 October 1957, 2.

[17] C. Kwa, Representations of nature mediating between ecology and science policy: the case of the International Biological Programme, *Social Studies of Science* 17 (1987) 413–442; J.D. Oldfield and D.J.B. Shaw, V.I. Vernadskii and the development of biogeochemical understandings of the biosphere, *c*.1880s–1968, *The British Journal for the History of Science* 46 (2013) 287–310.

[18] S.R. Weart, Global warming, Cold War, and the evolution of research plans, *Historical Studies in the Physical and Biological Sciences* 27 (1997) 330, 355; D.M. Hart and D.G. Victor, Scientific elites and the making of US policy for climate change research, *Social Studies of Science* 23 (1993) 643–680.

[19] For example, P. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*, Cambridge MA, 2010, 150–186.

[20] For example, linkages between East and West in this area were facilitated by the 1972 US-USSR Agreement on Cooperation in the Field of Environmental Protection as well as initiatives associated with the International Institute of Applied Systems Research established in Laxenburg, Austria in 1972.

as General Circulation Models (GCMs).

The establishment of large-scale data initiatives such as the WMO's World Weather Watch (WWW), and the persistent desire to grasp the complexities of the global climate system, moved the climate debate in some notable directions. In particular, it encouraged the development of an appreciation of the Earth system, which transcended regional, international and ideological divisions; creating an ‘infrastructural globalism’ according to Paul Edwards.[21] These developments functioned in tandem with a plethora of other globalizing trends linked to advances in remote sensing, a burgeoning environmental movement, and the emergence of concepts such as the biosphere and sustainable development.[22] These globalizing trends laid the foundations, at least in part, for an understanding of climate change which relied increasingly on the use of statistical modelling, while tending to marginalise other ways of interpreting the climate evident in the social sciences and humanities.[23] Tensions also emerged within the natural sciences community, with individuals such as the British meteorologist Hubert Lamb (1913–1997) arguing for an expansive, interdisciplinary approach to climate; one that included the examination of historical sources, in order to ensure a comprehensive observational base for related modelling activity.[24] The new breed of climate modellers was typically from a physics and mathematics background and their work embraced notions of scientific precision, which contrasted with the more interpretative science characteristic of Lamb's historical reconstruction of past climates. Nevertheless, this purported precision was of a particular kind, associated primarily with the techniques of statistical analysis and extrapolation. As such, the underlying assumptions framing any given model could vary markedly. Simon Shackley utilises the notion of ‘epistemic lifestyles’ in order to draw attention to the way in which different groups of modellers go about the task of constructing their climate models.[25] For Mike Hulme, the natural science-driven approach to climate change established itself firmly as the dominant interpretive framework during the period 1985–1992, effectively encompassing the early activities of the IPCC and the lead up to the 1992 Rio Conference on Environment and Development.[26] He terms the approach ‘climate reductionism’, conceptualising it as a form of neoenvironmental determinism with climate abstracted from the complexities of the broader socio-cultural context and thus removing human agency, amongst other things, from the debate.[27] Soviet scientists formed a significant element of this general initiative as will be discussed in more detail below.

Soviet climate science post-1945

English-language critiques of Soviet climate science and associated understanding are relatively limited, although there was certainly interest in the ideas and concepts of Soviet climate scientists amongst communities of Western physical scientists post-1945.[28] Taken together, this body of scholarship points towards the long history of meteorological and climatological science within the Soviet and Russian context and this includes a strong pre-revolutionary root.[29] A number of themes are evident within this tradition, which remained distinct throughout the course of the twentieth century. First, there was a strong emphasis on applied meteorology/climatology within Soviet science rooted in the traditions of the late tsarist period and driven forward by the particularities of the Soviet scientific model.[30] The prominence of applied work post-1917 (and particularly during the late Stalinist period) mirrored initiatives underway within most areas of Soviet science due to state coercion, and ensured considerable energy was channelled into the ways in which meteorology and climate science might benefit agriculture as well as other parts of the economy.[31] Second, there was a tendency to conceptualise climate as part of a broader global environmental system which integrated both organic and inorganic nature. This was influentially advanced by the pedologist V.V. Dokuchaev (1846–1903) and his school from the late nineteenth century via a number of different disciplinary pathways, and most notably via the work of V.I. Vernadsky (1863–1945).[32] Third, in developing his ideas, Vernadsky reflected on the growing influence of humankind on the biosphere grounded on the historical development of scientific thought and understanding, and postulated the emergence of what he termed the noosphere.[33] As part of this, Vernadsky acknowledged the constructive potential of human endeavour and expressed hope for the future in this regard. The Soviet Union's troubled environmental legacy ensured that the West tended to view such promethean views with caution.[34] Nevertheless, there was a noticeable trend within certain areas of Soviet science, including climatology, which acknowledged the likelihood of positive outcomes of human action grounded on detailed scientific understanding. Soviet scientific endeavour linked to climate change embodied these three characteristics to varying degrees. In particular, the work of individuals such as Kondrat'ev and Budyko reflected interest in conceptualising climate as part of a larger global physical system, of which more below. There was also a significant volume of work carried out on climate change linked to an interest in, for example, improving agricultural output in the fertile steppe region of European Russia, and individuals such as Budyko played leading roles in such endeavours.[35] Initiatives concerning specifically anthropogenic climate change had clear links to this applied tradition and yet at the same time moved beyond the domestic inclinations embedded in much state policy.

[21] Edwards, *A Vast Machine*, xviii, 187–227.

[22] W.C. Clark and R.E. Munn (Eds), *Sustainable Development of the Biosphere*, Cambridge, 1986.

[23] For example, S. Cohen, D. Demeritt, J. Robinson and D. Rothman, Climate change and sustainable development: towards dialogue, *Global Environmental Change* 8 (1998) 341–371; D. Demeritt, The construction of global warming and the politics of science, *Annals of the Association of American Geographers* 91 (2001) 307–337; Hulme, Reducing the future to climate.

[24] J. Martin-Nielsen, Ways of knowing climate: Hubert H. Lamb and climate research in the UK, *WIREs Climate Change* 6 (2015) 469.

[25] S. Shackley, Epistemic lifestyles in climate change modelling, in: C.A. Miller and P.N. Edwards (Eds), *Changing the Atmosphere: Expert Knowledge and Environmental Governance*, Cambridge MA, 2001, 107.

[26] Hulme, Geographical work, 6; Demeritt, The construction of global warming, 315–316.

[27] Hulme, Reducing the future to climate, 247.

[28] R.G. Ellingson, F. Baer, H.W. Ellsaesser et al., *Climate Research in the Former Soviet Union*, Foreign Applied Sciences Assessment Center, McLean VA, 1993; P.E. Lydolph, Soviet work and writing in climatology, *Soviet Geography* 12 (1971) 637–665.

[29] Oldfield, Mikhail Budyko's (1920–2001) contributions.

[30] L.R. Graham, *Science and Philosophy in the Soviet Union*, New York, 1972; N. Kremenstov, *Stalinist Science*, Princeton NJ, 1997.

[31] M.I. Budyko, Meteorologicheskie issledovaniya v SSSR, *Meteorologiya i Gidrologiya* 11 (1957) 7–16; M.S. Kulik, Agrometeorologicheskaya sluzhba za 40 let, *Meteorologiya i Gidrologiya* 11 (1957) 32–40.

[32] J.D. Oldfield and D.J.B. Shaw, *The Development of Russian Environmental Thought: Russian Scientific and Geographical Perspectives on the Natural Environment, 1880s-1960s*, London, 2016.

[33] J.D. Oldfield and D.J.B. Shaw, V.I. Vernadsky and the noosphere concept: Russian understandings of society-nature interaction, *Geoforum* 37 (2006) 145–154.

[34] For example, Josephson, Dronin, Cherp, Mnatsakanian, Efremenko and Larin, *An Environmental History of Russia*; P.R. Pryde, *Environmental Management in the Soviet Union*, Cambridge, 1991.

[35] M.I. Budyko, *Teplovoi Balans Zemnoi Poverkhnosti*, Leningrad, Gidrometeorologicheskoe izdatel'stvo, 1956; D.J.B. Shaw, Mastering nature through science: Soviet geographers and the Great Stalin Plan for the transformation of nature, 1948–53, *The Slavonic and East European Review* 93 (2015) 120–146.

M.I. Budyko is arguably the most well-known Soviet climatologist from a Western perspective. He began working at the Main Geophysical Observatory (GGO) in Leningrad during the 1940s, rising quickly through the ranks, and acting as its director from 1954 to 1972.[36] Budyko participated in the international debate around anthropogenic climate change as it developed from the late 1960s onwards.[37] His intellectual output can be usefully divided into three chronological stages: first, his early conceptual and applied work on the heat balance at the Earth's surface; second, a shift towards the global level via an interest in climate change and human influence on climate systems during the course of the 1960s; and third the development of a complex global understanding of climate situated within the all-encompassing concepts of the biosphere and global ecology from the late 1970s onwards.[38]

Budyko's shift into work concerning climate change and human influence on climate systems was part of a broader, albeit restricted, trend evident within the Soviet scientific literature during the late 1950s and early 1960s. A paper by the geophysicist E.K. Fedorov in 1958 can be considered an early effort to reflect on humankind's influence on meteorological processes, ranging from land-use changes, nuclear explosions, and shifts in the chemical state of the atmosphere.[39] Fedorov and Budyko were both key instigators of a specially convened meeting on the transformation of climate which took place in Leningrad during April 1961.[40] This meeting, together with a related workshop the following June, represented the first focussed Soviet discussions concerning anthropogenic climate change.[41] A 1962 paper by Budyko noted the growing influence of humankind on the climate system linked in particular to increased energy use.[42] This early intervention in the general debate reflected on the potential consequences of such trends for the Arctic region, a theme that Budyko would return to repeatedly in subsequent years.[43] Budyko's general approach to the issue of climate change was one of cautious optimism, and this would remain a feature of his work during the course of the next three decades.[44] For example, the complex role of the Arctic region's ice cover in regional and global climate processes was acknowledged. At the same time, he determined that if science suggested ice removal was feasible, having limited consequences for broader natural systems, then potential socio-economic benefits were in the offing.[45] Budyko's focus on the Arctic region was integral to his broader interest in the global energy regime, a topic that underpinned a widely cited article in the English-language journal *Tellus* in 1969.[46] This paper introduced a basic (semi-empirical) model which suggested that the global climate system was highly sensitive to the level of incoming solar radiation. As such, relatively small shifts in this value appeared to have the potential to initiate runaway cooling or heating with dramatic consequences for the Earth's climate system. Such insight was supported by analogous, albeit independent, work published by the American climatologist W.D. Sellers in the same year.[47] The implications of such work for the warming effect of increased anthropogenic CO2 emissions was underlined in a later publication by Budyko entitled *Atmospheric Carbon Dioxide and Climate*.[48]

In 1972, Budyko published the monograph, *Influence of Humankind on Climate* [*Vliyanie Cheloveka na Klimat*], which was subsequently held up by Soviet scientists as an early attempt to provide a realistic prognosis of future global temperature increases resulting from human activity. This publication is also important for the emphasis it placed on understanding past climates in order to anticipate future climatic conditions.[49] As the 1970s progressed, Budyko published a handful of papers with K.Ya. Vinnikov overviewing work related to climate change and the role of humankind in such change. These papers supported the idea of humankind's growing influence on the climate system and demonstrated a detailed engagement with Western scholarship concerning the potential warming consequences of anthropogenic CO2 emissions.[50] For Budyko, anthropogenic influence on the wider environment was generally reducible to three main causal factors, namely, increased concentrations of CO2, changing levels of aerosol pollution from industrial sources, and increased levels of heat/energy output from anthropogenic sources.[51] He considered the first two factors to be the dominant ones for the late twentieth century, with human energy output having the potential to gain in significance as the twenty-first century progressed.[52] Allied to this, he also suggested that in certain regions characterised by large urban development anthropogenic heat generation was already comparable with certain natural flows of heat.[53] Budyko's ideas in this area have been revisited in recent years. For example, E.J. Chaisson opened his paper on the subject by noting that:

> Even if civilization on Earth stops polluting the biosphere with greenhouse gases, humanity could eventually be awash in too much heat, namely, the dissipated heat by-product generated by any nonrenewable energy source.[54]

While Budyko's general work appears to be back in vogue, his projections have nevertheless been questioned, with Chaisson advancing, for example, a much slower growth in human heat emissions in comparison with incoming solar radiation.[55]

During the course of the 1970s and early 1980s Budyko

36 J. Houghton, *In the Eye of the Storm: The Autobiography of Sir John Houghton* (with Gill Tavner), Oxford, 2013, 49.

37 For example, M.I. Budyko, Polar ice and climate, in: J.O. Fletcher (Ed.), *Proceedings of the Symposium on the Arctic Heat Budget and Atmospheric Circulation*, January 31 through February 4, 1966, Lake Arrowhead, California. The Rand Corporation, Santa Monica CA, 1966, 5–21.

38 Oldfield, Mikhail Budyko's (1920–2001) contributions.

39 E.K. Fedorov, Vozdeistvie cheloveka na meteorologicheskie protsessy, *Voprosy Filosofii* 4 (1958) 138, 144.

40 A.P. Gal'tsov, Soveshchanie po probleme preobrazovaniya klimata, *Izvestiya Akademii Nauk SSSR: Seriya Geograficheskaya* 5 (1961) 128–133.

41 A.P. Gal'ltsov and A.S. Cheplygina, Vtoroe soveshchanie po probleme preobrazovaniya klimata, *Izvestiya Akademii Nauk SSSR: Seriya Geograficheskaya* 5 (1962) 184–187; M.I. Budyko and K.Ya. Vinnikov, Dvadtsat' pyat' let issledovanii antropogennogo izmenenie global'nogo klimata, *Meteorologiya i Gidrologiya* 10 (1986) 5.

42 M.I. Budyko, Izmenenie klimata i puti ego preobrazovaniya, *Vestnik AN SSSR* 7 (1962) 35–36.

43 M.I. Budyko, *Polyarnye L'dy i Klimat*, Leningrad, 1969.

44 M.I. Budyko, *Klimate v Proshlom i Budushchem*, Leningrad, 1980, 332.

45 M.I. Budyko, Polyarnye l'dy i klimat, *Izvestiya Akademii Nauk SSSR* 6 (1962) 10.

46 M.I. Budyko, The effect of solar radiation variations on the climate of the earth, *Tellus* 21 (1969) 611–619.

47 W.D. Sellers, A global climatic model based on the energy balance of the earth-atmosphere system, *Journal of Applied Meteorology* 8 (1969) 392–400.

48 M.I. Budyko, *Atmospheric Carbon Dioxide and Climate*, NASA Technical Translation, Washington D.C., 1974.

49 M.I. Budyko, *Vliyanie Chelovek na Klimat*, Gidrometeoizdat, Leningrad, 1972, 3.

50 M.I. Budyko and K.Ya. Vinnikov, Global'noe poteplenie, *Meteorologiya i Gidrologiya* 7 (1976) 16–26; M.I. Budyko and K.Ya. Vinnikov, Sovremennye izmeneniya klimata, *Meteorologiya i Gidrologiya* 9 (1973) 3–13.

51 M.I. Budyko, On present-day climatic changes, *Tellus* 29 (1977) 193–204.

52 M.I. Budyko, Vozmozhnye klimaticheskie posledstviya khozyaistvennoi deyatel'nosti chelovek, in: M.I. Budyko and M.P. Petrov (Eds), *Chelovek i Sreda Obitaniya*, Leningrad, 1974, 44–48.

53 M.I. Budyko, Antropogennye vliyaniya na klimat i puti ego preobrazovanniya, in: I.P. Gerasimov, A.G. Doskach, F.B. Konstantinov et al. (Eds), *Priroda i Obshchestvo*, Moscow, 1968, 255.

54 E.J. Chaisson, Long-term global heating from energy usage, *Eos* 89 (2008) 253; J.R. Fleming, Comment on 'Long-term global heating from energy use', *Eos* 89 (2008) 531.

55 E.J. Chaisson, Reply to comment on 'Long-term global heating from energy use', *Eos* 89 (2008) 531.

developed his work on climate in order to place it more firmly within a broader conceptual framework of global ecology. Indeed, his 1977 book on this theme posited global ecology as an emerging area of great potential.[56] This, and later work, advanced the global environment as a relatively fragile entity that required careful oversight of human activity in order to ensure its continued functioning. At the same time, Budyko's approach was also characterised by a persistent technocratic belief in the ability of humankind to understand the earth's complex natural systems thus resulting in its effective management.

Budyko published a number of articles on the general theme of anthropogenic climate change and future predictions of such change during the late 1980s, which coincided with the activities of the IPCC. A key text, and one which would feature prominently in the findings of the IPCC's Working Group II report (see below), was co-edited with Yuri Izrael' and entitled *Anthropogenic Climate Change*.[57] This volume was referred to by Budyko in a later article as providing 'the fullest description [to date] of forthcoming climate change', with its projections of temperature and rainfall maps for much of the Northern Hemisphere during the first half of the twenty-first century.[58] Importantly, the map predictions were based primarily on the use of past climate reconstructions, which were then used as analogues for understanding possible future climates, although certain findings from climate theory were also incorporated.[59] As will be discussed below, the general methodology of utilising past climate analogues would come under significant pressure from the Western modelling fraternity during the IPCC process due to concerns over the robustness of resultant future climate predictions.[60] In response to such criticism, Budyko intimated that Soviet scientists were aware of the limitations of relying too heavily on past climate analogues and, furthermore, had progressed a relatively expansive approach to the issue since the 1970s, which combined meteorological observations and certain elements of climate theory together with palaeoclimatic data from past warm epochs. He went on to suggest that the promotion of an empirical approach 'wholly independent from the conclusions of climate theory' had the potential to provide an important check with respect to the findings of modelling activities. Furthermore, the use of both empirical and modelling approaches promised to 'increase the reliability of information concerning climatic conditions of the future'.[61] Budyko's defence of an empirical approach, and in particular the use of palaeoclimatic reconstructions, was restated again in a 1991 article in the Russian-language journal *Meteorologiya i Gidrologiya*, noting that such work allowed for an appreciation of the inherent sensitivity (*chuvstvitel'nost'*) of the Earth's climate to shifts in the chemical composition of the atmosphere.[62]

Budyko was joined in his global level theorising by the geophysicist Kirill Ya. Kondrat'ev. Kondrat'ev gained domestic and international recognition for his work in areas linked to solar radiation, satellite meteorology and remote sensing.[63] Kondrat'ev also worked extensively with the international scientific community and this included strong links with the WMO. During the 1980s, Kondrat'ev began to give global environmental change a significant amount of attention, and this included the specific issue of global climate change.[64] His work in this area was characterised by a number of general themes. First, while he considered the debate concerning anthropogenic climate change of significance, he was at the same time wary of over-simplifying the issue as well as the inadequacies of available datasets.[65] In particular, he understood the climate system as just one facet or expression of the Earth's global physical system.[66] Second, this expansive understanding of the climate system ensured that he placed emphasis on the functioning of the biosphere as a whole, and resisted reducing the climate issue down to single factors such as an increase in CO2 emissions.[67] This general approach was evidenced in his support for the work of V.G. Gorshkov concerning biotic regulation. This concept is predicated on the belief that the fundamental tension between society and the wider environment can only be addressed through the restoration and long-term conservation of significant parts of the biosphere.[68] The notion of biotic regulation refers to the self-regulating properties of the biosphere, which it is postulated have developed over the long term. It is suggested that there is a threshold level of 'anthropogenic perturbation' beyond which the integrity of this regulating function is compromised.[69] Third, his work during the late 1980s emphasised the importance of utilising data from various analogues in order to provide deeper insight into global climate change. In addition to the value of examining past climates of the Earth, Kondrat'ev also advocated an analysis of the climate systems of other planets.[70] His interest in utilising analogues was also evident in his work on the effects of nuclear war on the atmosphere.[71]

In light of the above it can be suggested that Soviet engagement with the international discussion around climate change was characterised by a growing awareness of the scope and nature of society's influence on climate systems, particularly with respect to CO2 and aerosol pollution, a concerted effort to establish future scenarios of climate change, and a positive engagement with analogous Western science in this area. At the same time, Soviet work related to future climate scenarios became increasingly defined, at least on the international level, by a dependence on palaeoclimatic analogues, and this emphasis would precipitate a marked stand-off between the Soviet contingent and the Western-dominated community of climate modellers during the formulation

56 M.I. Budyko, *Global'naya Ekologiya*, Moscow, 1977.

57 M.I. Budyko and Yu. A. Izrael, *Antropogennye Izmeneniya Klimata*, Leningrad, 1987. The English language version was published in 1991 by the University of Arizona Press.

58 M.I. Budyko and P.Ya. Groisman, Poteplenie 80-x Godov, *Meteorologiya i Gidrologiya* 3 (1989) 5.

59 M.I. Budyko, Empiricheskaya otsenka prestoyashchikh izmenenii klimata, *Meteorologiya i Gidrologiya* 10 (1989) 6. The Soviet Union had a strong tradition of work in palaeoclimatology as evidenced by the work of geographers such as K.K. Markov (1905–1980) and I.P. Gerasimov (1905–1985). For example see *Gorizonty Geografii. K 100-Letiyu K.K. Markova*, Moscow, 2005.

60 T. Skodvin, *Structure and Agent in the Scientific Diplomacy of Climate Change: An Empirical Case Study of Science-Policy Interaction in the Intergovernmental Panel on Climate Change*, Dordrecht, 2000, 138–142.

61 Budyko, Empiricheskaya otsenka, 5–6, 13.

62 M.I. Budyko, Analogovyi metod otsenki predstoyashchikh izmenenii klimata, *Meteorologiya i Gidrologiya* 4 (1991) 40.

63 A.A. Buznikov, Tvorcheskii put' Kirilla Yakovlevicha Kondrat'eva, in: *Akademik Kirill Yakovlevich Kondrat'ev: Iz Pokoleniya Pobeditelei*, St. Petersburg, 2007, 9–25; A.P. Cracknell, V.F. Krapivin and C.A. Varotsos, The seminal nature of the work of Kirill Kondratyev, in: A.P. Cracknell, V.F. Krapivin and C.A. Varotsos (Eds), *Global Climatology and Ecodynamics: Anthropogenic Changes to Planet Earth*, Chichester, 2009, 1–16.

64 Buznikov, Tvorcheskii put', 20.

65 K.Ya. Kondrat'ev, *Global'nyi Klimat*, St. Petersburg, 1992, 325–329.

66 K.Ya. Kondrat'ev, *Global'nyi Klimat*, Volume 17, Seriya Meteorologiya i Gidrologiya, Moscow, 1987, 3.

67 Buznikov, Tvorcheskii put', 21; K.Y. Kondratyev, The Bulletin interviews: Professor K.Y. Kondratyev, *WMO Bulletin* 47 (1998) 12.

68 The concept has overlap with the Gaia theory proposed by James Lovelock in that both advance the notion that the Earth's organic and inorganic systems interact in complex ways in order to determine system-wide stability.

69 V.G. Gorshkov, V.V. Gorshkov, A.M. Makarieva (Eds), *Biotic Regulation of the Environment: Key Issues of Global Change*, Chichester, 2000, 329–339.

70 Kondrat'ev, *Global'nyi Klimat*, 3; K.Ya. Kondrat'ev, *Planeta Mars*, Leningrad, 1990; K.Ya. Kondratyev and G.E. Hunt, *Weather and Climate on Planets*, Oxford, 1982.

71 K.Ya. Kondratyev, *Climate Shocks: Natural and Anthropogenic*, New York, 1988.

of the first IPCC report.[72]

Soviet climate change dialogue with the West

The remainder of the paper traces Soviet involvement in scientific dialogue with Western counterparts linked to deepening awareness of anthropogenic climate change. In view of space limitations, the paper focuses on three areas of particular note for the advancement of climate change understanding: the Nuclear Winter debate, US-USSR environmental collaboration and associated initiatives, and finally the activities leading up to and including the publication of the first IPCC report in 1990.

As background, it is worth acknowledging the relative difficulties characterising the movement of scientific knowledge during the Cold War period linked to ideological as well as linguistic barriers. Post-1945, climate science became entangled with broader issues such as climate modification and the effects of nuclear fallout, and the urgency of these concerns encouraged some to pursue scientific conduits between East and West in spite of the various administrative and political barriers in place. International bodies such as the WMO facilitated the exchange of ideas by supporting short fact-finding visits to the Soviet Union as well as encouraging collaborative work amongst its members. Nevertheless, the level of exchange was relatively low and the situation was aggravated by the language barrier, which reduced Western engagement with Soviet science and thus only served to heighten the uncertainty and suspicion underpinning the relationship.[73] In the area of climatology, efforts were made by bodies such as the American Geophysical Union (AGU) to facilitate the exchange of ideas, in this case via the activities of its Russian Translation Board.[74] The American Meteorological Society was also active in publishing a series of reviews of Soviet meteorological science in its *Bulletin* during the course of the 1950s and 1960s. Such initiatives were buttressed by the focussed activity of 'think-tank' organisations including the RAND Corporation, which emerged as an influential mediator of Russian language materials.[75]

Nuclear winter dialogue

The Nuclear Winter debate emerged as a key area of concern during the 1980s due to the anticipated impact of a significant nuclear exchange on the Earth's atmospheric processes. Jacob Hamblin makes the point that 'in the United States, the sharpest dispute about climate change in the 1980s was not about carbon dioxide but rather about the possibility of "Nuclear Winter"'.[76] Some felt that the Soviets took advantage of the general idea around Nuclear Winter for political gain, by making a case for the reduction of nuclear weapon stockpiles and thus helping to ease its own chronic economic problems. Hamblin's account also posits the weak computing abilities of the Soviets at this time, a fact which made the US question the Soviet Union's ability to accurately model and interpret the potential consequences of a nuclear strike.[77]

There is undoubtedly some truth in this negative appraisal of Soviet engagement. However, it does underplay the longstanding interest of Soviet scientists in this general area. Soviet observations on the potential climatic consequences of nuclear explosions date back to the 1950s.[78] In addition, individuals such as E.K. Fedorov had been long-time advocates of caution in the use of nuclear weaponry as well as climate modification at the international level.[79] Budyko, together with the climatologist G.S. Golitsyn and Yuri Izrael', published the book *Global Climatic Catastrophes* in 1986 (English edition 1988), which addressed the issue of nuclear climatic change directly. In their preface they asserted the longstanding nature of Soviet work in this area including research on 'aerosol climatic catastrophe', which dated back to the 1970s and had been, it was argued, a precursor to understanding the climatic impact of a nuclear war.[80]

Soviet scientists were also involved in the broader international collaborative effort to consider the links between nuclear weaponry and the climate.[81] For example, an initiative by ICSU (SCOPE-ENUWAR) brought together several hundred scientists in order to 'appraise the state of knowledge of the possible environmental consequences of nuclear war'.[82] This resulted in the publications of two volumes in the SCOPE series in 1986, namely, *Environmental Consequences of Nuclear War: Physical and Atmospheric Effects* (volume 1) and *Ecological, Agricultural and Human Effects* (volume 2). The steering committee of the initiative included the Soviet academician G.K. Skryabin and a significant number of Soviet scientists took part in associated workshops and meetings. Soviet scientists were also participants in the review work by the WMO in this general area. Following a meeting of the WMO's Joint Scientific Committee, G.S. Golitsyn and the US scientist N.A. Phillips (National Meteorological Center, Washington DC) were tasked with evaluating existing state of the art concerning the atmospheric impacts of nuclear explosions.[83] The resultant publication underlined the potential serious consequences of a nuclear exchange for atmospheric processes, but at the same time drew attention to the continued uncertainties associated with the basic predictive models. This was followed a year later by a further WMO publication, in which Golitsyn was joined by M.C. MacCracken of the Lawrence Livermore National Laboratory, California, where a similar conclusion was reached.[84]

[72] Work on past climates formed an important element of Western climate science. For example, the Climate Research Unit at the University of East Anglia has a long tradition of research in this area as evidenced by an early intervention in the debate in 1980, see T.M.L. Wigley, P.D. Jones and P.M. Kelly, Scenario for a warm, high-CO2 world, *Nature* 283 (1980) 17–21. The author would like to thank one of the reviewers for highlighting this early work.

[73] For example, W.A. Baum, A study of reference citations in the Journal of Meteorology and the Quarterly Journal of the Royal Meteorological Society, *Bulletin of the American Meteorological Society* 36 (1955) 62 and Collis and Dodds, Assault on the unknown, 568.

[74] H.E. Landsberg, The translation program, *Eos* 53 (1972) 867.

[75] D. Hounshell, The Cold War, RAND, and the generation of knowledge, 1946–1962, *Historical Studies in the Physical and Biological Sciences* 27 (1997) 237–267; Fletcher, *Changing Climate*; J.O. Fletcher, *Managing Climatic Resources*, Santa Monica CA, 1969.

[76] Hamblin, *Arming Mother Nature*, 137.

[77] Hamblin, *Arming Mother Nature*, 237–239.

[78] Fedorov, Vozdeistvie cheloveka.

[79] E.K. Fedorov, The Bulletin interviews: E.K. Fedorov, *WMO Bulletin* 30 (1981) 256–257.

[80] M.I. Budyko, G.S. Golitsyn and Y.A. Izrael, *Global Climatic Catastrophes*, Berlin, 1988, vi.

[81] L. Badash, *A Nuclear Winter's Tale: Science and Politics in the 1980s*, Cambridge MA, 2009, 224–226; P. Rubinson, The global effects of nuclear winter: science and antinuclear protest in the United States and the Soviet Union during the 1980s, *Cold War History* 14 (2014) 61.

[82] SCOPE-ENUWAR Steering Committee, Foreword, in: A.B. Pittock, T.P. Ackerman, P.J. Crutzen, M.C. MacCracken, C.S. Shapiro and R.C. Turco (Eds), *Environmental Consequences of Nuclear War: Physical and Atmospheric Effects, Volume I*, SCOPE 28, Chichester, 1986, xxi. SCOPE (Scientific Committee on Problems of the Environment) was one of ICSU's committees. ENUWAR refers to the Environmental Consequences of Nuclear War initiative.

[83] G.S. Golitsyn and N.A. Phillips, *Possible Climatic Consequences of a Major Nuclear War, The World Climate Research Programme*, WMO/TD 99, ICSU/WMO, 1986.

[84] G.S. Golitsyn and M.C. MacCracken, *Possible Climatic Consequences of a Major Nuclear War*, WMO/TD 201, ICSU/WMO, 1987, 2.

US-USSR climate science collaboration

US-USSR interaction with respect to the science of climate change was also evident as part of more purposeful collaboration between the two countries. For Stephen Brain, the specific context of the Cold War, with its emphasis on rivalry and competition, encouraged favourable engagement with the global environment.[85] This assertion finds expression in the emergence of initiatives such as the International Institute for Applied Systems Analysis (IIASA) in Austria, which was driven primarily by the two superpowers.[86] A further long-term environmental cooperation programme between the Soviet Union and the US was initiated in the early 1970s. N.A. Robinson and G.R. Waxmonsky suggest a combination of politically expedient as well as mutually beneficial reasons was behind the relative success of this bilateral initiative.[87] The two presidents (Nixon and Brezhnev) supported the signing of the *US-USSR Agreement on Cooperation in the Field of Environmental Protection* on 23 May 1972. It consisted of eleven thematic areas and this included a focus on air pollution as well as the influence of the environment on climate (Working Group VIII). E.K. Fedorov and Yuri Izrael' were installed as chair and coordinator of the Soviet contribution in view of their leading roles in the State Hydrometeorological Service (Izrael' would become co-chair from 1974). At this time, the State Hydrometeorological Service was a relatively weak institution within the context of the broader Soviet political machinery and D.R. Kelley suggests that as its power grew, Izrael' became less interested in the collaborative endeavour.[88]

There was a general recognition that the Soviet Union and the USA shared a range of common environmental problems, in spite of their ideological differences.[89] In addition, the prevailing rhetoric suggested that both sides anticipated benefits from the agreement beyond the general political aspects of the initiative. Soviet prowess was said to reside in their system of protected areas centred on the *zapovedniki* (areas given high levels of protection within the Soviet Union), as well as in fields such as ecological assessment.[90] At the same time, the Soviet Union gained from US applied and technical expertise linked to national park management and environmental monitoring equipment.[91] The various initiatives were complemented by a series of workshops and symposia which brought together scientists from both sides around themes such as the comprehensive analysis of the environment and nature reserves as well as climate change.[92]

More specifically, Working Group VIII was established to examine 'the influence of environmental changes on climate'. According to Kelley, the US side had initially hoped to gain from Soviet understanding in the area of climate science. However, while collaborative work around climate change was considered a general success, the US participants concluded that the USSR had been 'at least a decade behind the United States in the area of climate research'.[93] The specifics of this assessment are not clear, but they are likely to refer primarily to the Soviet Union's computer modelling capabilities.[94] At the same time, other reports are suggestive of US interest in at least some areas of Soviet modelling activity.[95]

Working Group VIII was co-chaired by Budyko and the American Alan D. Hecht (US Environmental Protection Agency). It pursued a relatively extensive joint programme over the course of more than fifteen years enrolling a significant number of scientists and institutions on both sides. It also facilitated the exchange of scientists between the US and the Soviet Union and resulted in a number of joint publications.[96] The work of the group was predicated on a general acceptance on both sides that 'global warming would be inevitable as a consequence of the on-going perturbations to atmospheric composition'.[97] The main emphasis of the activities carried out by the working group was to establish a firm basis on which to predict future changes in climate associated with a warming trend.

Two main directions of research were pursued with respect to predicting future climates, one examined past climates and reflected on the value of such knowledge for current understanding, and the other pathway focussed on theory and modelling of contemporary climates. As noted, this latter area was one in which Soviet science trailed its American counterpart.[98] While the report itself does not make explicit reference to the nature of the input from the two sides, the two pathways reflected the relative strengths of the Soviet and US contributors.[99] In reviewing the book that emerged out of the long-term collaboration between the two countries (entitled *Prospects for Future Climate*), the US climatologist William W. Kellogg noted that:

> In general, the United States scientists rely heavily (but not exclusively) on the theoretical results of experiments with a hierarchy of climate models, whereas the Soviet scientists emphasize a more empirical approach that relies on reconstructions of past climates and studies of current trends.[100]

While the differences in approach evidenced by the two parties were an accepted part of the US-USSR collaboration, they would take on a much more divisive hue within the high politics of the early IPCC discussions.

Soviet involvement in the activities of the WMO and IPCC

The Soviet Union had a visible presence within the World Meteorological Organisation (WMO) reflecting in part its historical role in the preceding International Meteorological Organisation, as well as the importance of such a vast country for the success of a

[85] S. Brain, The appeal of appearing green: Soviet-American ideological competition and Cold War environmental diplomacy, *Cold War History* 16 (2014) 443–462.
[86] Rindzeviciute, *The Power of Systems*, 52–72.
[87] N.A. Robinson and G.R. Waxmonsky, The U.S.-U.S.S.R. Agreement to Protect the Environment: 15 years of cooperation, *Environmental Law* 18 (1988) 436–440; D.R. Kelley, Environmental protection and conservation, in: N. Jamgotch (Ed.), *U.S.-Soviet Cooperation: A New Future*, New York, 1989, 86.
[88] Kelley, Environmental protection, 90, 92.
[89] Yu. Izrael' and B. Kuvshinnikov, SSSR-SSHA: sotrudnichestvo v oblasti okhrany prirodnoi sredy, *Mezhdunarodnaya Zhizn'* 2 (1975) 34.
[90] Izrael' and Kuvshinnikov, SSSR-SSHA: sotrudnichestvo, 35–36.
[91] Robinson and Waxmonsky, The U.S.-U.S.S.R. Agreement to Protect the Environment.
[92] Yu.A. Izrael' (Ed.), *Vsestoronnii Analiz Okruzhayushchei Prirodnoi Sredy. Trudy Sovetsko-Amerikanskogo Simpoziuma*, Leningrad, 1975; I.I. Borzenkova, Sovetsko-Amerikanskoe soveshchanie ekspertov 'Prichiny sovremennykh izmenenii klimata', *Izvestiya Akademii Nauk: Seriya Geograficheskaya* 2 (1987) 108.
[93] Kelley, Environmental protection, 105.
[94] Ellingson, Baer, Ellsaesser et al., *Climate Research in the Former Soviet Union*.
[95] E.W. Bierly and J.A. Mirabito, The US-USSR Agreement on Protection of the Environment and its relationship to the US National Climate Program, *Bulletin American Meteorological Society* 65 (1984) 18.
[96] For example, V.P. Meleshko and R.T. Wetherald, The effect of a geographical cloud distribution on climate: ;a numerical experiment with an atmospheric General Circulation Model, *Journal of Geophysical Research* 86:C12 (1981) 11995–12014. See also Bierly and Mirabito, The US-USSR Agreement, 16.
[97] M.C. MacCracken, M.I. Budyko, A.D. Hecht and Y.I. Izrael, *Prospects for Future Climates: A Special US/USSR Report on Climate and Climate Change*, Lewis MI, 1990, xi.
[98] MacCracken, Budyko, Hecht and Izrael, *Prospects for Future Climates*, xii, 1.
[99] Ellingson, Baer, Ellsaesser et al., *Climate Research in the Former Soviet Union*, VI-8.
[100] W.W. Kellogg, Book review of Prospects for Future Climate: A Special US/USSR Report on Climate and Climate Change, *Climatic Change* 20 (1992) 83.

world meteorological initiative. Key positions were held by Soviet academics including E.K. Fedorov (vice-president, 1963–1971) and Yu.A. Izrael' (first/second vice-president, 1975–1987), and individuals such as Budyko, Kondrat'ev and G.S. Golitsyn were also heavily involved in different aspects of the organisation's work over the years.[101]

The 1979 World Climate Conference was an event of significance with respect to the developing momentum around climate change.[102] The WMO executive committee decision to hold such a meeting was taken in 1977 based on the need to understand and plan for climatic variability as well as the 'strong evidence that the climate itself may be influenced by the activities of mankind'.[103] The first week of the conference was devoted to the delivery of invited papers on current knowledge, and week two provided a forum for discussion and reflection in order to determine recommendations for future areas of focus. More than twenty Soviet representatives attended the meeting. Furthermore, four of the main discussion papers were delivered by Soviet scientists in the first week, and included a paper by Fedorov (Climate change and human strategy) in the opening session, as well as papers by the geographer I.P. Gerasimov (Climates of past geological epochs), and physical scientists G.I. Marchuk (Modelling of climatic changes and the problem of long-range weather forecasting) and Yu. A. Izrael' (Climate monitoring and climate data collection services for determining climatic changes and variations). In addition, A.V. Sidorenko and V.A. Kovda acted as session chairs and Ju.S. Sedunov was co-chair of the working group on research on climate change and variability. Fedorov's paper is particularly noteworthy in view of its delivery in the opening session. With reference to human influence on climate, he noted three main mechanisms: changes to the land surface with consequences for heat exchange, changes to the water balance again impacting linked physical systems, and changes to the transparency of the atmosphere leading to shifts in the Earth's energy balance.[104]

As noted, 1985–1992 is considered of key importance by Mike Hulme, with the suggestion that it was during this period that the current dominant framing of climate change in both science and policy circles was fashioned.[105] In particular, it was a period during which modelling emerged as the key 'epistemological authority' and this approach was utilised in order to abstract climate from its complex entanglements with a range of physical as well as social phenomena, to be used as a main predictor of the future. Hulme goes further in his critique, referring to it as 'epistemological slippage – a transfer of predictive authority from one domain of knowledge to another without appropriate theoretical or analytical justification'.[106]

The period was opened by the activities of the Second Joint UNEP/ICSU/WMO International Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts held in Villach, Austria in 1985, and concluded with the 1992 United Nations Framework Convention on Climate Change (UNFCCC).[107] Sonja Boehmer-Christiansen draws attention to the pivotal nature of the Villach conference in helping to propel the climate change debate into the political sphere. The conference gave rise to the Advisory Group on Greenhouse Gases (AGGG), which paved the way for the IPCC in 1988, with the latter emerging in part due to apparent US concerns that the climate change issue should remain more firmly under the control of a state-driven body.[108]

The first session of the UNEP/WMO sponsored IPCC took place in Geneva in November 1988. The Soviet Union sent a principal delegate (A.P. Metalnikov) and four advisors (S.S. Hodkin, E. Konigin, V. Blatov and B. Smirnov) and its supporting statement to the opening session highlighted Soviet enthusiasm for the work of the panel and the need for greater understanding of the climate change issue.[109] The opening meeting established the basic outline of the panel's activities which were to be structured around three main areas: an assessment of the science concerning climate change (Working Group I), an assessment of the potential socio-economic impacts of climate change (Working Group II), and the formulation of response strategies (Working Group III).[110] Yuri Izrael' was nominated as chair of Working Group II. Furthermore, Soviet representation was formally allocated to the other two working groups.[111] By the next meeting of the general IPCC body in February 1989, Working Group II had delineated five areas for further work (agriculture, forestry and land use; natural ecosystems; hydrology and water resources; energy, industry, transport, settlements and human health; world oceans, cryosphere and human health). In addition to Izrael' as chair, each of the five sub-groups was allocated a Soviet specialist.[112] A steering group was also established during the first meeting of Working Group II in Moscow (February 1989) and this incorporated a Soviet representative.[113] The focus of Working Group II on an assessment of the impacts of climate change ensured that it required robust scientific insight into the anticipated extent and regional character of climate warming. However, this aspect of its work was undermined by the apparent slow emergence of relevant scenario recommendations from Working Group I, a point that was underlined at the third plenary meeting in Washington D.C. in early 1990.[114]

The IPCC process was clearly a difficult one, stemming from the complexity of the climate change issue, the silo-like working practices of the panel's working groups, the political connotations of its work, and the inevitable clash of views and personalities that became evident as the process evolved.[115] During the preparatory phase of the IPCC's first report, an international ministerial conference was held at Noordwijk (The Netherlands, November 1989) on *Air Pollution and Climate Change*. For Boehmer-Christiansen, this

[101] For example, the World Weather Watch idea emerged out of the joint work of the Soviet climatologist V.A. Bugaev and US climatologist Harry Wexler during their time at the WMO.

[102] Yu.A. Izrael', Vsemirnaya konferentsiya po klimatu, *Meteorologiya i Gidrologiya* No. 7 (1979) 5–7.

[103] WMO, *World Climate Conference: A Conference of Experts on Climate and Mankind*, Geneva, February 1979, WMO, Geneva, 1979, vii.

[104] E.K. Fedorov, Climatic change and human strategy, in: WMO, *World Climate Conference*, 14–15.

[105] Hulme, Geographical work at the boundaries, 6.

[106] Hulme, Reducing the future to climate, 249.

[107] The Villach meeting involved the Soviet physicist/climatologist G.S. Golitsyn (b. 1935).

[108] Boehmer-Christiansen, Science policy, the IPCC and the Climate Convention, 376–377, 380.

[109] Report of the First Session of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC), Geneva, 9–11 November 1988, IPCC-1, TD-No. 267, Annex III, 10–11.

[110] IPCC-1, TD-No. 267, 4.

[111] IPCC-1, TD-No. 267, Annex 5.

[112] Report of the First Session of the IPCC Bureau, Geneva, 6–7 February 1989, IPCC-2, TD-No. 294, 5.

[113] Report of the Second Session of the WMO/UNEP IPCC, Nairobi, 28–30 June 1989, IPCC-3, 12.

[114] Report of the Third Session of the WMO/UNEP IPCC, Washington D.C., 5–7 February 1990, IPCC-5, 19; see also Yu. A. Izrael', Issledovaniya vliyaniya izmeneniya klimata, *Meteorologiya i Gidrologiya* 4 (1991) 29.

[115] S. Boehmer-Christiansen, Global climate protection policy: the limits of scientific advice. Part 1, *Global Environmental Change* 4 (1994) 147; S. Boehmer-Christiansen and J. Skea, The operation and impact of the Intergovernmental Panel on Climate Change: results of a survey of participants and users, *STEEP Discussion Paper No. 16*, University of Sussex, 1994; B. Bolin, *A History of the Science and Politics of Climate Change: The Role of the Intergovernmental Panel on Climate Change*, Cambridge, 2007.

event was part of a marked politicization of the climate change debate, and provided evidence of ‘the deep split between Europe and the USA, as well as within the IPCC itself’.[116] She goes on to note that:

> Battle lines were now clearly drawn inside the IPCC, then in the process of drafting its first report. It could not afford to offend major governments or its sponsors. Born into the controversy over response strategies, it had already become a target for conflicting pressures. One of its first actions would be to discredit the Soviet view, stated by Professor Izreal [sic] at home, that global warming was a good thing, and reducing Soviet influence in WGI [Working Group I].[117]

For Alan Hecht, writing in the foreword to the English-language edition of Izrael' and Budyko's book *Anthropogenic Climate Change* (1987), the notion of a possible favourable future climate for parts of the northern hemisphere was grounded on the results of the application of palaeoclimatic analogues outlined in the book.[118] Budyko's insistence on the potential beneficial impacts of climate change, primarily through anticipated increased levels of precipitation and the so-called ‘fertilizer effect’ of heightened CO2 levels (enhancing crop growth), clashed with Western climate modellers as well as the emerging international consensus that anthropogenic climate change was an issue to be addressed with growing urgency. The somewhat crude and dogmatic character of Budyko's pronouncements during the late 1980s differed from his more cautious and measured statements in early years, and his views were understandably treated with scepticism by many.[119]

The evident marginalisation of the Soviet contingent persisted along overtly scientific lines, framed by the growing dominance of a predictive, law-based modelling approach within Working Group I of the IPCC.[120] In particular, doubt was cast over the future climate predictions of the palaeo-analogue approach (pushed strongly by the Soviet representatives), due to uncertainties over the underlying mechanisms and the robustness of datasets, as well as suggestions that past climates would be unable to accurately predict the specificities of a rapidly warming global climate in the near future.[121] In view of the importance of Working Group I for the whole IPCC enterprise, its emphasis on a modelling approach had negative consequences for the relative standing of Soviet scientific input. In recounting this period, the then chair of Working Group I, John Houghton (former chief executive of the UK Meteorological Office), highlights a more personal consequence of this shift in emphasis. He suggests that Budyko was greatly affected by the critique of his work on the use of past climate analogues at a special meeting of Working Group I that took place in Bristol.[122] At the same time, it is important to note that the move towards the use of General Circulation Models (GCMs) was not total as evidenced by the findings of the aforementioned US-USSR collaborative endeavour around climate change (published in 1990), which emphasised the initiative's ‘innovative approach to projecting future climate change based on the hypothesis that we can combine the strengths of what we have learned about past warm periods and what we can simulate with our models’.[123] While the politics of international collaboration were clearly at play here, it is also reasonable to conclude that the scientists involved were generally supportive of this general conclusion. Crucially, however, in the final report of Working Group I, it was explained that GCMs were ‘the most highly developed tool which we have to predict future climate’.[124] The value of palaeoclimates for predictive purposes was also highlighted, although with qualification:

> We cannot therefore advocate the use of palaeo-climates as predictions of regional climate change due to future increases in greenhouse gases. However, palaeo-climatological information can provide useful insights into climate processes, and can assist in the validation of climate models.[125]

The slow emergence of conclusions from Working Group I prompted the incorporation of palaeoclimate analogues into the predictive scenarios utilised by Working Group II.[126] The final report for Working Group II made a clear distinction between the Soviet palaeoclimate approach and the Western use of GCMs. The related discussion suggested that the relative merits of both approaches were open to ongoing debate.[127] The summative work of Izrael' and Budyko with respect to palaeoclimatic analogues, published in *Anthropogenic Climate Change*, was referenced extensively within the report. In Izrael's account of events, he suggested that the recommendations of Working Group I were both late and also characterised by uncertainties linked primarily to predictions of rainfall and soil moisture, as well as extreme events at the regional scale.[128] He also promoted the potential value of palaeoclimatic analogues, highlighting the fact that they provided an additional ‘validation’ of climate models and possessed the capability to deliver regionally sensitive predictions concerning rainfall.

Conclusion

The Soviet case study advanced here provides insight into a hitherto little studied aspect of the evolving climate change debate during the Cold War period, one which was nevertheless influential in helping to advance a natural science understanding of the phenomenon at the international level. Indeed, shaped by a handful of highly visible climatologists and geophysicists, it is evident that Soviet science was a significant presence with respect to the

[116] S. Boehmer-Christiansen, Global climate protection policy: the limits of scientific advice. Part 2, *Global Environmental Change* 4 (1994) 189–190.

[117] S. Boehmer-Christiansen, Global climate protection policy, 190.

[118] A.D. Hecht, Foreword, in: M.I. Budyko and Yu.A. Izrael, *Anthropogenic Climatic Change*, Tuscon, 1987, ix-x, ix. See also M.I. Budyko, A.B. Ronov, A.L. Yanshin, *History of the Earth's Atmosphere*, Berlin, 1987, 130; Budyko, *Klimate v Proshlom*; M.I. Budyko, Past changes in climate and societal adaptations, in: J.B. Smith, N. Bhatti, G.V. Menzhulin, R. Benioff, M. Campos, B. Jallow, F. Rijsberman, M.I. Budyko and R.K. Dixon (Eds), *Adapting to Climate Change: An International Perspective*, New York, 1995, 16–26.

[119] J. Miller and F. Pearce, Soviet climatologist predicts greenhouse ‘paradise’, *New Scientist* 1679 (26 August 1989) 24; Skodvin, *Structure and Agent*, 138–142.

[120] Demeritt, The construction of global warming, 315–316.

[121] Bolin, *A History of the Science and Politics of Climate Change*, 63–65; Ellingson, Baer, Ellsaesser, et al., *Climate Research in the Former Soviet Union*, VI-9-10.

[122] Houghton, *In the Eye of the Storm*, 144–145. It seems likely that Houghton was referring to a meeting in Bath (UK) during November 1989. See Skodvin, *Structure and Agent*, 140.

[123] MacCracken, Budyko, Hecht and Izrael, *Prospects for Future Climates*, 1; see also Ellingson, Baer, Ellsaesser, et al., *Climate Research in the Former Soviet Union*, VI-11-12.

[124] J.T. Houghton, G.J. Jenkins and J.J. Ephraums (Eds), *Climate Change: The IPCC Scientific Assessment*, Cambridge, 1990, xxv.

[125] Houghton, Jenkins and Ephraums, *Climate Change*, xxv. The IPCC's engagement with palaeoclimatic research would gain greater visibility within its subsequent reports and remains an area of debate. For example, C.J. Caseldine, C. Turney and A.J. Long, IPCC and palaeoclimate – an evolving story?, *Journal of Quaternary Science* 25 (2010) 1–4.

[126] See also Cohen, Demeritt, Robinson and Rothman, Climate change and sustainable development, 345–346.

[127] W.J.McG. Tegart, G.W. Sheldon and D.C. Griffiths, *Climate Change: The IPCC Impacts Assessment*, Canberra, 1990, 1-1, 1-1-1-2.

[128] Izrael', Issledovaniya vliyaniya, 29–30. See also K.Ya. Kondrat'ev, II Vsemirnaya konferentsiya po klimatu, *Vestnik Rossiiskoi Akademii Nauk* 5 (1991) 132–133, 136.

strengthening international consensus around anthropogenic climate change. Allied to this, the scientific record is suggestive of a distinctive Soviet engagement with the issue, grounded on a long tradition of interest in the role of climate in the functioning of complex physical and biological systems. This tradition was further characterised by a general emphasis on what might be termed an holistic approach towards understanding climate change, one that emphasised the complex character of the climate system, as well as the potential of humankind to use its understanding of the climate system for the wider benefit of society. Elements of this particular feature of Soviet climate science remain relatively underdeveloped in Western accounts of the climate change debate.

Soviet climate science appears to have been held in high regard by Western scientists throughout much of the Cold War period. For example, the Soviet Union's work concerning physical climatology, led by Budyko and his colleagues at the GGO, was well received, and Soviet work on climatic analogues proved significant within the work of bodies such as the WMO. At the same time, there was a growing sense that Soviet developments in climate science, and particularly climate modelling, lagged behind achievements in the West as the 1970s and 1980s unfolded, linked to the slowdown in the Soviet economy and associated technological inadequacies rather than any fundamental scientific shortcomings. While Soviet scientists certainly made progress in the formulation of climate models, the purported limitations in computing power are likely to have been a key factor behind the increased emphasis placed on palaeoclimatic analogues by the Soviets on the international stage; an emphasis which contrasted with the growing Western interest in statistical modelling. Budyko's evident support of this approach, as a key player internationally, was undoubtedly a further reason for Soviet prominence in this area. Importantly, both sides recognised the value of the two approaches for advancing the climate change issue. However, there was growing debate at the international level as to their relative value and this was framed by a complex mix of scientific coalitions and high politics. It also seems likely that the dominance of the Soviet Union's international agenda by a relatively small group of ageing scientists resulted in the gradual ossification of their collective input and an increasingly dogmatic approach to their own work, thereby helping to undermine relationships with Western colleagues and disguise more varied domestic debates. Ultimately, the marked shift towards the use of GCMs as the key science of climate change forecasting during the late 1980s, allied to scientific uncertainties over aspects of the analogue approach as well as personality clashes, appears to have resulted in the relative marginalisation of Soviet scientific input during the formative stages of the first IPCC report. Thus, Soviet contributions to the scientific debate around climate change at the international level moved from a position of significance during the 1960s-1980s to a position of relative isolation by the start of the 1990s. A state of affairs amplified by a tendency for the climate debate to revolve around the science of future predictions and the growing significance of advanced climate modelling activity.

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