Review of "The Remarkable Scientist and Writer Ukichiro Nakaya and His "Black Moon" and "White Moon" Worlds" by Kevin Hamilton and Wataru Ohfuchi

General Comments

Nakaya occupies a prominent position in the history of science owing to his pioneering contributions to the study of snow-crystal morphology, most notably through the development of the Nakaya diagram. In addition to this widely recognized achievement, he contributed to several other areas of physical science. His biography is therefore of considerable interest not only to historians of meteorology and cryospheric science but also to scholars interested more broadly in the development of modern experimental research. This is particularly the case because many of his investigations required the creation of experimental methods and instrumentation that were not yet available. Furthermore, parts of his scientific career unfolded under historical circumstances that presented significant challenges for academic research. Additional discussion of these technical, institutional, and historical constraints would further illuminate the context in which his achievements were realized.

As with any scientific biography, the manuscript seeks to balance the personal dimensions of Nakaya's life with an account of his scientific accomplishments and their subsequent influence. The personal and emotional aspects of his experiences provide valuable insight into his character and motivations, while his scientific contributions form the basis of his lasting historical significance. Achieving an appropriate balance between these complementary perspectives is therefore an important objective.

The manuscript provides a rich account of Nakaya's personal experiences and reflections, drawing extensively on his own writings. At the same time, readers of a journal such as *History of Geo- and Space Sciences* may also welcome a more detailed discussion of aspects that are central to the history of science, including experimental methodology, instrumentation, measurement techniques, and the validation of scientific results. Greater attention to these topics would further strengthen the manuscript's contribution to understanding Nakaya's role in the development of modern experimental science.

In particular, it may be helpful to provide additional background regarding the scientific context in which Nakaya's research was conducted. A discussion of the state of knowledge at the time, the outstanding scientific questions, and the reasons these questions were considered important would allow readers to appreciate more fully the significance of his achievements. Such context would be valuable both for his early studies of electrical discharges and for his later investigations of snow-crystal formation in ice cores.

The manuscript could also highlight more explicitly the considerable experimental challenges associated with the study of snow crystals. Crystal growth occurs under non-equilibrium conditions of supersaturation, and the creation and maintenance of such conditions in a laboratory environment represented a major technical accomplishment. Because supersaturation is continuously reduced by condensation on surrounding surfaces and cannot be measured directly, the design of his equipment and interpretation of these experiments required considerable ingenuity. A more detailed account of these methodological challenges would help readers appreciate the originality and sophistication of Nakaya's work.

Similarly, it may be useful to note that natural cloud environments are characterized by turbulence and vertical transport processes that cannot be fully reproduced under laboratory conditions. Against this background, Nakaya's success in identifying the principal environmental parameters governing crystal morphology appears particularly noteworthy. Additional discussion of these limitations and their implications would further emphasize the importance of his achievements.

Nakaya's most influential contributions were fundamentally phenomenological. By systematically documenting the relationships between environmental conditions and crystal forms, he established an empirical framework that later became the foundation for theoretical investigations. The Nakaya diagram remains significant not because it provided a complete physical explanation of crystal growth but because it identified robust patterns that subsequent research sought to explain in additional detail. The

manuscript could benefit from a brief discussion of how modern research has built upon Nakaya's findings and how his contributions are viewed from a contemporary scientific perspective.
Comparable observations apply to Nakaya's investigations of the physical properties of ice, both in laboratory studies and in his work on Greenland ice cores.
The present manuscript offers an engaging description of the personal circumstances surrounding these investigations. A much more fuller treatment of the scientific motivations, the state of knowledge at the time, the methods employed, and the advances achieved would further enhance its value to readers interested in the history of science.
Overall, the manuscript presents a valuable and highly readable account of Nakaya's life and work. Its contribution could be strengthened further by giving greater emphasis to the scientific questions, experimental methods, and knowledge advances that underpinned Nakaya's lasting impact on the development of modern geophysical and cryospheric research.

Recommendations

Regarding the current version of Nakaya's biography, which places considerable emphasis on emotional experiences, it should be noted that emotions arise immediately, whereas reflection on a scientific problem and the development of a viable research strategy require substantial time and effort. In its present form, the manuscript would be suitable for a journal with a primarily popular or general-interest orientation. For publication in a journal devoted to the history of science, however, substantial revisions are necessary. While the descriptions of emotional experiences should be reduced considerably, difficult situations undoubtedly involved significant emotional strain and should therefore not be omitted entirely.
A very brief historical introduction should mention the views of Albertus Magnus, who around 1250 noted that snow crystals consistently exhibit a hexagonal form. Olaus Magnus published the first illustrations of snow crystal shapes in Uppsala in 1555 (English edition available from 1996, p. 52), although many of these woodcuts were highly imaginative. He remarked that the closer one approaches the North Pole, the greater the variety of snow figures becomes; one may sometimes observe fifteen to twenty or even more different forms in a single day. Nevertheless, his illustrations bear little resemblance to actual snow crystals. Later, Johannes Kepler documented his reflections on snow crystal morphology in *Strena seu de nive sexangula* (1611). Assuming water-vapor particles to be spherical, he explored various geometric packing arrangements but did not arrive at a convincing explanation for the diversity of snow crystal forms. It would be of considerable interest to learn whether Nakaya was familiar with any of these earlier authors. That he was most probably inspires by Bentleys photographs has already been mentined.
The current state of knowledge is described in detail by Libbrecht (2021: Snow crystals: a case study in spontaneous structure formation), who also provides an extensive appreciation of Nakaya's work. It was seen that additional crystal forms develop that were not yet identified by Nakaya. His biography would benefit from an assessment of his historical significance from a modern scientific perspective. But still today the role of fractal growth mechanisms remains only partially understood and could provide an informative context for evaluating Nakaya's contributions.
Nakaya's findings concerning the elasticity of Greenland ice cores should likewise be evaluated in light of present-day state of knowledge. Such an assessment would help readers appreciate both the originality and the lasting significance of his work.
Overall, the manuscript should be shortened appreciably, particularly in those sections devoted to Nakaya's personal feelings and popular-science films and essays. HGSS offers the possibility of providing supplementary materials, including audiovisual content. This opportunity could be used to preserve the more detailed emotional narratives for interested readers while keeping the main text focused on scientific achievements and their significance. The main body of the manuscript should be largely free of such material and concentrate primarily on Nakaya's scientific results and their contribution to the advancement of knowledge.

Special comments:
Lines 33–36: The mention of Nobel Prize winners does not appear to be relevant to Nakaya's scientific biography. Unless a direct connection to his research or intellectual development can be established, this section should be omitted.
Line 275: A brief overview of the historical development of snow crystal research would be appropriate here. In particular, the contributions of Albertus Magnus, Olaus Magnus, Johannes Kepler, and possibly René Descartes (*Les Météores*, 1637) could be summarized.
Line 299: It should be clarified whether Nakaya's laboratory facilities were inadequate for continuing his work on electrical sparks or for initiating research on radioactivity.
Line 308: How did Nakaya experimentally investigate the electrical nature of snow crystals, and what were the results of these investigations?
Line 311: Seligman's review should be replaced by the more scientifically informed assessment provided by Libbrecht (2021). Since Libbrecht does not discuss Seligman's review, the latter appears outdated from a modern perspective.
Line 359: The text implies that Nakaya required approximately two years of preparatory work before successfully producing first artificial snow crystals. This highlights the meticulous and careful nature of his experimental approach and deserves explicit mention.
Line 385: Was Nakaya's proposal for the standardization of English terminology describing different crystal forms ever adopted? A brief explanation would be useful.
Line 398: This section could be shortened. The praise received by Nakaya's film at the 1948 General Assembly of the International Union of Geodesy and Geophysics in Norway could instead be mentioned in a dedicated section shortly summarizing his public outreach activities.
Lines 495–500: Criticism of Nakaya's collaboration with the military should be treated with caution or omitted, since the historical circumstances and conditions under which this collaboration occurred remain unclear. Greater emphasis should instead be placed on the scientific results obtained, particularly given their relevance to civil aviation and the existence of comparable research programs in other countries.
Lines 515–517: If this change in research direction was never actually implemented, it should be omitted.
Lines 518–522: To reduce the length of the manuscript, the Japanese-language publications should be listed only in an appendix.
Line 523: Section 3.11 should focus on the scientific results and the resulting advances in knowledge. However, the fact that this collaboration emerged from a desire for postwar reconciliation should be retained.
Line 613: Section 4 is excessively detailed. Nakaya's popular-science activities should be summarized more concisely, while detailed information could be transferred to supplementary material.
Line 819: It would be helpful to explain whether "Black Moon" refers to the second new moon within a calendar month and why Nakaya chose this metaphor for the Mauna Loa expedition. Is there a connection to the rarity of snowfall in Hawaii? Presumably, Nakaya aimed to verify his laboratory findings through observations under natural conditions. If so, the manuscript should indicate whether this objective was achieved. The more emotional and narrative elements of this section could be moved to the supplementary materials.
Lines 823 ad 1012: The number of words is not important, please omit that.
Lines 930–937: In my interpretation, the trade-wind inversion plays the dominant role in controlling the concentration of condensation nuclei. The inversion suppresses vertical mixing, resulting in pristine background atmospheric conditions above the inversion and boundary-layer conditions below it. Human settlements influence aerosol concentrations up to the inversion layer. Did Nakaya publish these observations and was he aware of the trade-wind inversion?
Line 972: Petterson was a visiting professor; this should be stated explicitly.

Line 1000 onwards: How did temperature and supersaturation change in association with the observed changes in crystal morphology ontop of Mauna Loa? Was a frontal passage involved? How was supersaturation measured on Mauna Loa, allowing comparison with Nakaya's morphology diagram?
Line 1009: What is the meaning of the metaphor "White Moon"? A brief explanation would be helpful.
Line 1012: The number of words is not scientifically meaningful and can be omitted.
Line 1032: It is particularly important that Nakaya emphasized the possibility of analyzing air bubbles trapped in ice to determine CO_2 concentrations and thereby infer anthropogenic emissions. Although he was not the originator of this idea, he contributed to promoting the method. In this context, the work of Scholander, who analyzed CO_2 within bubbles in icebergs during the early 1950s, should be mentioned. The numerous direct quotations in this section could be removed and replaced with a concise discussion of the early development of this analytical approach.
Line 1430: Does this statement mean that there was insufficient time to prepare for the expedition, or that Nakaya had not expected to obtain ice cores that could later be examined in the laboratory in Japan? This point should be clarified.
Line 1511: The publication list should be divided into scientific and popular-science publications.