ETHICAL IMPLICATIONS AND LEGAL VOID IN CLOUD SEEDING AS A WAR STRATEGY

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Abstract

Cloud seeding, a technology that manipulates rainfall patterns, presents a potential military advantage in the 21st century. However, its use in warfare raises serious ethical and legal concerns. This paper looks into the moral complexities of weaponising cloud seeding. It analyses the environmental threats posed by manipulating weather systems, the potential harm to civilians caught in engineered storms, and the disruption it could cause to delicate ecosystems. The paper further exposes the inadequate legal framework surrounding this technology. Existing treaties like the Environmental Modification Convention (ENMOD) and the Hague Conventions have loopholes that leave room for debate on their application. Additionally, regulations vary greatly between countries, highlighting the need for a unified global approach to cloud seeding. To address these gaps, the paper proposes a comprehensive legal framework. It suggests strengthening existing treaties, reinterpreting international law with a focus on environmental protection, and even creating a new treaty specifically outlawing military cloud seeding. Ultimately, the paper emphasises the crucial role of international cooperation and responsible governance. It argues that cloud seeding should be used for peaceful purposes, such as managing droughts or floods. Only through international collaboration can we ensure that this technology serves humanity and does not end up as a tool for war.

***Keywords**:* Cloud Seeding, Weather Modification, War Strategy, International Law

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Introduction

The fast-changing complexity of modern warfare presents a constant challenge for decision-makers. Technological advancements blur the lines between traditional and non-traditional tactics, raising concerns about unforeseen consequences. One particularly troubling area of focus is the potential weaponisation of weather modification techniques. Among these techniques, cloud seeding emerges as a capability that's both ethically questionable and strategically interesting. Cloud seeding disrupts the natural rain cycle. Introducing specific substances, like silver iodide or dry ice, into clouds influences ice crystal formation, ultimately promoting or inhibiting rainfall.[1] This technology holds immense benefits for drought mitigation and agricultural management in peacetime. Imagine vast arid regions receiving life-giving rain or drought-stricken farmlands experiencing a much-needed boost in crop yields. However, the potential for manipulation in conflict situations raises serious concerns that should be further investigated.

The concept of manipulating weather patterns for military purposes is not a novel one. Historical records offer glimpses of attempts to influence rainfall as far back as ancient China, where emperors sought to control agricultural outcomes. However, the 20th century witnessed a significant escalation with the rise of organized scientific research and experimentation. During the Vietnam War, the United States' "Operation Popeye" employed cloud seeding techniques over the Ho Chi Minh Trail, aiming to disrupt enemy supply lines by triggering heavy rainfall and mudslides.[2] While ultimately deemed ineffective, this covert operation, declassified in the 1970s, serves as a conscious reminder of the destructive potential of weather warfare. The excitement of cloud seeding as a military strategy lies in its ability to disrupt enemy operations in a seemingly bloodless manner. Imagine a scenario where a nation can manipulate weather patterns to trigger floods in enemy territory, hindering troop movements, destroying infrastructure, and disrupting agricultural production. Conversely, the ability to control rainfall could be used to create droughts, crippling agricultural production and hindering enemy logistics.

[1] Edith Brown Weiss. (2020). Climate Change and Geoengineering the Climate. Brill | *Nijhoff EBooks*, 216–268. <https://doi.org/10.1163/9789004422018_010>

[2] Olson, K. R. and Speidel, D. R. (2023). United States Secret War in Laos: Long-Term Environmental and Human Health Impacts of the Use of Chemical Weapons. *Open Journal of Soil Science*, 13(04), 199–242. <https://doi.org/10.4236/ojss.2023.134009>

However, the ethical implications are profound. Unintended consequences, such as floods or droughts, can devastate entire regions, inflicting harm on civilian populations and ecosystems far beyond the intended target zone. A country attempting to disrupt enemy supply lines with heavy rain risks causing widespread flooding in its border regions, displacing civilians and causing immense economic damage. The long-term environmental repercussions also remain largely unexplored. Disrupting natural weather patterns in one region could have dangerous effects on global climate systems, potentially triggering droughts or extreme weather events in other parts of the world.

The absence of clear international regulations governing the use of cloud seeding in warfare creates a critical legal void. This legal ambiguity creates a dangerous uncertainty, leaving nations free to interpret existing treaties in ways that could potentially legitimize the use of cloud seeding for military purposes. Existing treaties like the Environmental Modification Convention (ENMOD) aim to prohibit military environmental modification techniques with "widespread, long-lasting or severe effects" (Art. I, 1). However, the interpretation of "widespread" and "severe" remains open to debate, creating a potential loophole for the use of cloud seeding, which may not always produce these extreme consequences[3]. Similarly, principles within the Hague Conventions and the Geneva Conventions offer some potential legal grounds for regulating cloud seeding based on proportionality and limitations on causing unnecessary environmental damage (Hague Convention (IV) Respecting the Rights and Duties of Neutral Powers in Case of War on Land, Art. 23(g);

Article23(g):

> It is especially forbidden...
>
> To destroy or seize the enemy's property, unless such destruction or seizure be imperatively demanded by the necessities of war.

Additional Protocol I to the Geneva Conventions, Art. 55(1)). However, the ambiguity surrounding the specific language and the lack of a comprehensive framework leave significant gaps.

[3]Ishfaq, S. (2022, September 10). Environmental Modification – A War Without Weapons. Retrieved August 11, 2024, from *Paradigm Shift website*: https://www.paradigmshift.com.pk/war-without-weapons/.

Article 55(1):

> Care shall be taken in warfare to protect the natural environment against widespread, long-term, and severe damage. This protection includes a prohibition of the use of methods or means of warfare which are intended, or may be expected, to cause such damage to the natural environment and thereby to prejudice the health or survival of the population.

The historical record offers cautionary tales of the potential dangers of weather modification experiments. The Lynmouth Flood of 1952 in Devon, United Kingdom, which claimed 35 lives, remains a controversial event. While officially attributed to an act of nature, declassified documents suggest that the Royal Air Force (RAF) may have been conducting cloud-seeding experiments in the region as at the time, raising questions about the potential link between these experiments and the devastating flood [4].

The international community has recognized the potential dangers of weather warfare. The ENMOD Convention, which entered into force in 1978, prohibits signatory states from engaging in military or any other hostile use of environmental modification techniques with "widespread, long-lasting or severe effects" (Art. I, 1). However, the treaty's effectiveness is limited by the fact that not all nations are signatories. Notably, China, a country with a growing weather modification program, is not a party to the ENMOD Convention.[5]This raises concerns about the potential for unregulated manipulation of weather patterns with the potential to destabilize entire regions. The case of China's growing weather modification program further highlights the urgency of addressing the legal and ethical issues surrounding this technology. China has openly stated its ambition to become a leader in weather modification by 2025, with plans to significantly expand its artificial rainfall and snowfall operations[6]. While China maintains that its program is for peaceful purposes, neighboring countries like India view these developments with

[4] Vidal, J., and Weinstein, H. (2001, August 30). RAF rainmakers "caused 1952 flood." Retrieved August 11, 2024, from the *Guardian website*: <https://www.theguardian.com/uk/2001/aug/30/sillyseason.physicalsciences>

[5] Jash, A. (2024, March 15). Is China modifying the weather? India has concerns. Retrieved August 11, 2024, from orfonline.org website: <https://www.orfonline.org/expert-speak/is-china-modifying-the-weather-india-has-concerns>

[6] Griffiths, J. (2020, December 3). China to expand weather modification program to cover area larger than India. Retrieved August 11, 2024, from *CNN website*: <https://edition.cnn.com/2020/12/03/asia/china-weather-modification-cloud-seeding-intl-hnk/index.html>

suspicion, particularly given China's proximity to the Tibetan Plateau, a crucial source of water for the region.[7] The potential for unintended consequences and the lack of international consensus on the use of weather modification for military purposes create a precarious situation.

This paper will investigate the historical use of weather modification for military purposes, analyze the legal frameworks surrounding this technology, and explore the ethical and environmental considerations. This paper seeks to address a critical gap in our understanding of the ethical predicament associated with weaponized cloud seeding. We will analyze the current fragmented legal landscape, highlighting the limitations of existing treaties such as the Environmental Modification Convention (ENMOD). Furthermore, we will propose a framework for responsible regulation of this technology in the context of armed conflict. This framework will necessitate international cooperation and the establishment of a robust legal framework that strengthens existing treaties, reinterprets existing international law through an environmental protection lens, and potentially establishes a dedicated treaty specifically prohibiting cloud seeding for military purposes.

Problem Statement

The military application of cloud seeding technology presents a complex challenge to international security, environmental stability, and global governance in the 21st century. While offering potential tactical advantages in warfare, such as disrupting enemy logistics and creating advantageous battlefield conditions, these benefits are overshadowed by critical concerns. The absence of comprehensive international regulations governing military cloud seeding creates dangerous ambiguity, threatening environmental integrity and global security frameworks. This problem focuses on three primary areas namely unintended environmental consequences, conflict escalation and geopolitical tensions, and accountability and enforcement challenges.

Unintended Environmental Consequences

Cloud seeding involves deliberately manipulating natural weather patterns by introducing substances like silver iodide or dry ice into cloud formations to influence precipitation.[8]However,

[7]Jash, A. (2024, March 15). Is China modifying the weather? India has concerns. Retrieved August 11, 2024, from orfonline.org website: <https://www.orfonline.org/expert-speak/is-china-modifying-the-weather-india-has-concerns>

the ramifications extend far beyond the immediate target area, potentially triggering acascade of unintended environmental consequences. The interconnectedness of global weather systems means that alterations in one region can have far-reaching and unpredictable impacts elsewhere. China's ambitious weather modification program, aiming to cover an artificial rainfall operation area exceeding 5.5 million square kilometers by 2025, illustrates the scale of potential environmental impact.[9]The long-term ecological effects of repeated cloud seeding operations remain poorly understood, with potential consequences for biodiversity, soil composition, and water quality. The cumulative impact could exacerbate broader environmental challenges related to climate change and ecological stability.

The potential for cloud seeding to cause indiscriminate harm to civilian populations and the environment conflicts with established principles of distinction and proportionality in armed conflict. Unlike conventional weapons, weather manipulation effects are not easily contained within designated combat zones. Altering weather patterns could lead to widespread civilian suffering through crop failures, water shortages, or natural disasters, raising serious concerns about compliance with international humanitarian law.

Escalation of Conflict and Geopolitical Tensions

The ambiguity surrounding the legal status of cloud seeding in warfare introduces unpredictability into international relations. The potential for weather modification as a first-strike tactic or part of a broader military strategy blurs the lines between conventional and unconventional warfare, potentially lowering the threshold for armed conflict. The subtle, delayed, and geographically dispersed effects of weather modification make it challenging to attribute responsibility definitively, creating a precarious situation where nations might employ cloud seeding preemptively, fearing their adversaries might do the same. This scenario could trigger a dangerous escalation spiral, with nations retaliating against perceived weather manipulation with their own atmospheric interventions or conventional military responses.

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[8] Edith Brown Weiss. (2020). Climate change and geoengineering the climate. Brill | *Nijhoff EBooks*, 216–268. <https://doi.org/10.1163/9789004422018_010>

[9] Griffiths, J. (2020, December 3). China to expand weather modification program to cover area larger than India. Retrieved August 11, 2024, from *CNN website*: <https://edition.cnn.com/2020/12/03/asia/china-weather-modification-cloud-seeding-intl-hnk/index.html>

Recent geopolitical tensions highlight the potential for weather modification to amplify existing conflicts. In 2012, Iranian President Mahmoud Ahmadinejad accused unnamed enemies of dispersing rain clouds over Iran, attributing droughts and crop losses to alleged weather warfare.[10]While the Iranian Vice President Hassan Mousavi was quoted to have declared the event as an acute issue and soft war by the West. The situation in South Asia provides another example, with India expressing growing concerns over China's weather modification activities in the Tibetan Plateau, viewing them as a potential threat to national security[11]. Given the strained relations between these nuclear-armed neighbors, the perception of weather manipulation as a hostile act could significantly escalate tensions. Furthermore, the difficulty in distinguishing between civilian and military applications of cloud-seeding technology complicates the international response, as legitimate weather modification for agricultural or water management purposes could be misconstrued as hostile acts.

The rapid advancement of weather modification technologies presents a classic arms race dilemma. As nations invest in developing more sophisticated cloud seeding capabilities, others may feel compelled to follow suit to maintain strategic parity. China's ambitious weather modification program, aiming to achieve a "developed weather modification system" by 2025 and reach a "worldwide advanced level" by 2035 exemplifies this trend and could prompt other nations to accelerate their own research and development efforts. This technological competition carries the risk of outpacing the development of appropriate legal and ethical frameworks to govern the use of these powerful capabilities.

Accountability and Enforcement Challenges

The absence of a robust international legal framework specifically addressing military applications of cloud seeding creates significant challenges in terms of accountability and enforcement. Without clear norms and agreed-upon standards, holding nations accountable for the misuse of weather modification technologies or enforcing future regulations becomes difficult. This legal vacuum could incentivize the proliferation of cloud seeding capabilities

[10]Wolchover, N. (2012, September 11). Could Iran's Enemies Really Be Destroying Its Rain Clouds? Retrieved August 13, 2024, from *NBC News website*: <https://www.nbcnews.com/id/wbna48993677>

[11]Jash, A. (2024, March 15). Is China modifying the weather? India has concerns. Retrieved August 11, 2024, from orfonline.org website: <https://www.orfonline.org/expert-speak/is-china-modifying-the-weather-india-has-concerns>

among state and potentially non-state actors, as the perceived military advantages might outweigh the uncertain legal consequences. The situation is further complicated by the dual-use nature of cloud seeding technology, which has legitimate civilian applications in agriculture and water resource management [12].

The current international legal landscape offers limited recourse for nations that may suffer environmental damage or civilian casualties as a result of another country's cloud seeding activities. Existing frameworks such as the Environmental Modification Convention (ENMOD) prohibit the hostile use of environmental modification techniques with widespread, long-lasting, or severe effects. However, the convention's effectiveness is limited by its broad language and the difficulty in proving that specific weather events were the result of intentional manipulation[13]. The lack of universal participation in relevant international agreements further complicates the situation, with China, a leader in weather modification technology, not being a signatory to the ENMOD Convention.[14]This creates potential loopholes and inconsistencies in the global governance of weather modification technologies, allowing some nations to operate outside the constraints of international norms.

Addressing the above listed challenges requires a comprehensive approach to developing international law concerning the military application of cloud seeding. Key questions to be addressed include how international law can be updated to effectively address the unique challenges presented by military applications of cloud seeding, considering the potential for unintended environmental consequences. Additionally, mechanisms need to be established to monitor and verify compliance with regulations, given the difficulties in attributing weather events to intentional manipulation. Finally, the international community must balance the need for accountability and enforcement with the legitimate interests of states in developing weather modification technologies. The ultimate goal is to establish a robust legal framework that promotes the responsible use of cloud seeding and prevents its exploitation for hostile purposes,

[12] Shevchenko, O. and Horiacheva, K. (2021). Impact of Weather Change Technologies on Global Security. *Land Forces Academy Review, 26(4),* 321–327. <https://doi.org/10.2478/raft-2021-0042>

[13]Ishfaq, S. (2022, September 10). Environmental Modification – A War Without Weapons. Retrieved August 11, 2024, from Paradigm Shift website: <https://www.paradigmshift.com.pk/war-without-weapons/>

[14]Jash, A. (2024, March 15). Is China modifying the weather? India has concerns. Retrieved August 11, 2024, from orfonline.org website: <https://www.orfonline.org/expert-speak/is-china-modifying-the-weather-india-has-concerns>

while addressing the ethical implications that extend beyond the immediate context of conflict, raising questions about humanity's relationship with nature and the limits of acceptable intervention in natural systems.

Literature Review

The use of weather modification techniques, particularly cloud seeding, for military purposes presents a complex challenge in international law and ethics. This review examines the existing legal frameworks, historical precedents, and contemporary developments related to weather modification activities, highlighting the significant gaps in regulation that this study aims to address. The legal landscape surrounding cloud seeding in warfare is characterized by a patchwork of international treaties and conventions that, while not explicitly addressing weather modification, provide some potential avenues for regulation. The Hague Conventions of 1907, foundational to international humanitarian law, prohibit actions such as "wanton destruction of property" and "employment of poisons or poisoned weapons" (Hague Convention (IV) Respecting the Rights and Duties of Neutral Powers in Case of War on Land, Art. 23(g); Art. 23(a)). While cloud seeding is not specifically mentioned, the principles of proportionality in attack and avoiding unnecessary suffering could potentially be applied to argue against its use in military operations.

Similarly, the Geneva Conventions of 1949, particularly Protocol I, offer another layer of potential regulation. Article 55 of Protocol I prohibits "widespread, long-lasting or severe damage to the natural environment" as a consequence of military operations (Additional Protocol I to the Geneva Conventions, Art. 55(1))[15]. This could potentially be interpreted to limit the use of cloud seeding if its effects are deemed to fall under this definition. However, the ambiguity surrounding the terms "widespread," "long-lasting," and "severe" creates uncertainty in application. The Environmental Modification Convention (ENMOD) of 1976 provides a more focused approach to the issue, explicitly prohibiting environmental modification techniques with

[15] Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977. (2022). Art. 55. Retrieved August 13, 2024, from ICRC website: <https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-48>

"widespread, long-lasting or severe effects" for military purposes[16]. However, the effectiveness of ENMOD is limited by its narrow scope and lack of robust enforcement mechanisms. The convention only applies to a specifically listed set of techniques, and it remains unclear whether cloud seeding is explicitly included. This creates a potential loophole that nations could exploit to argue that their cloud-seeding activities fall outside the treaty's scope.

Beyond these core conventions, other international agreements offer additional, albeit limited, legal considerations. The UN Convention on the Law of the Non-Navigational Uses of International Watercourses acknowledges the right to utilize shared water resources for cloud seeding while emphasizing the responsibility to avoid causing harm to the environment of other states sharing the resource (Art. 5).[17] The Convention on Biological Diversity and its Nagoya Protocol require nations to ensure their cloud seeding practices don't negatively impact biodiversity and necessitate obtaining consent from local communities before initiating such activities. Additionally, the Convention on Long-Range Transboundary Air Pollution regulates the emission and transport of air pollutants generated by cloud seeding processes.[18]

The historical case of "Operation Popeye," a covert US cloud seeding program conducted during the Vietnam War, serves as a critical example of the potential military application of weather modification techniques. This operation, which aimed to disrupt enemy supply lines by triggering rainfall over the Ho Chi Minh Trail, highlights the real-world implications of using cloud seeding as a weapon and the lack of clear legal boundaries surrounding such actions.[19] More recently, China's ambitious weather modification program provides a contemporary case study of large-scale weather alteration capabilities. While ostensibly for civilian purposes, China's plan to expand its weather modification system to cover an area of 5.5 million square kilometers by 2025 has raised concerns among neighboring countries, particularly India. This

[16]Vöneky, S. (2020). Freiburger Informations papierezum Völkerrecht und ÖffentlichenRecht Limiting the Misuse of the Environment during Peacetime and War -*The ENMOD Convention*. Retrieved from <https://www.jura.uni-freiburg.de/de/institute/ioeffr2/downloads/online-papers/FIP%202020_05_Voeneky_ENMOD-Convention_final.pdf>

[17] UNGA Convention on the Law of the Non-Navigational Uses of International Watercourses (adopted 21 May 1997, entered into force 17 August 2014) A/RES/49/52, art 5.

[18] Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity (adopted 29 October 2010, entered into force 12 October 2014), art 7.

[19] Olson, K. R., and Speidel, D. R. (2023). United States Secret War in Laos: Long-Term Environmental and Human Health Impacts of the Use of Chemical Weapons. *Open Journal of Soil Science, 13(04),* 199–242. <https://doi.org/10.4236/ojss.2023.134009>

program, involving the deployment of fuel-burning chambers on Alpine slopes in the Tibetan Plateau region, demonstrates the potential scale and sophistication of modern weather modification efforts.[20]The ethical considerations surrounding cloud seeding in warfare are multifaceted and intertwined with legal and environmental concerns. The potential for civilian harm and unintended consequences is a primary ethical dilemma. Cloud seeding can have unpredictable and far-reaching impacts, potentially causing widespread water shortages which could lead to food insecurity and displacement of civilians[21]. These consequences could disproportionately impact vulnerable communities already facing environmental challenges.

Furthermore, the use of cloud seeding in warfare raises questions about adherence to the principle of distinction, a fundamental tenet of international humanitarian law requiring combatants to distinguish between military objectives and civilian populations[22]. The indiscriminate nature of weather modification makes it challenging to ensure that its effects are limited to military targets, potentially violating this principle. The long-term environmental implications of manipulating weather patterns remain largely unknown. Cloud seeding could disrupt delicate ecological balances, impacting plant and animal life, and potentially exacerbating existing environmental problems like desertification.[23]The potential for these actions to contribute to or intensify climate change adds another layer of ethical complexity to the use of weather modification in warfare.

The existing works reveals significant gaps in the legal and ethical frameworks governing the use of cloud seeding in warfare. The absence of a comprehensive, dedicated international treaty specifically addressing weather modification for military purposes leaves room for potential misuse and exploitation. The existing legal instruments, while providing some basis for regulation, lack the specificity and enforcement mechanisms necessary to effectively govern the

[20]Jash, A. (2024, March 15). Is China modifying the weather? India has concerns. Retrieved August 11, 2024, from orfonline.org website: <https://www.orfonline.org/expert-speak/is-china-modifying-the-weather-india-has-concerns>

[21]Bruintjes, R. T. (1999). A Review of Cloud Seeding Experiments to Enhance Precipitation and Some New Prospects. *Bulletin of the American Meteorological Society, 80(5)*, 805–820. <https://doi.org/10.1175/1520-0477(1999)080%3C0805:arocse%3E2.0.co;2>

[22] Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977. (2022). Art. 48. Retrieved August 13, 2024, from *ICRC website*: <https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-48>

[23]Kuhl, L. (2022, August 11). Dodging silver bullets: how cloud seeding could go wrong. Retrieved August 13, 2024, from *Bulletin of the Atomic Scientists website*: <https://thebulletin.org/2022/08/dodging-silver-bullets-how-cloud-seeding-could-go-wrong/>

use of this technology in conflict situations. The scientific uncertainty surrounding the long-term environmental and societal impacts of cloud seeding further complicates efforts to establish clear legal boundaries. Without a full understanding of the potential consequences, it becomes challenging to define and enforce concepts like "widespread, long-lasting or severe effects" as outlined in the ENMOD Convention. Moreover, the international community's fragmented approach to regulating cloud seeding in warfare highlights the need for a more unified and comprehensive strategy. The lack of standardized regulations across countries and the absence of regional initiatives specifically targeting this issue create a potentially dangerous situation where accountability for misuse might be difficult to establish. This paper aims to address these gaps by proposing a more robust legal framework specifically tailored to the challenges posed by cloud seeding in warfare. This research aims to contribute to the development of laws and regulations governing the use of weather modification techniques in military contexts by examining the limitations of existing treaties, analyzing historical precedents, and considering contemporary developments. The focus is on minimizing potential environmental damage, protecting civilian populations, and preventing the unintended escalation of conflicts through the misuse of cloud seeding technology.

In conclusion, this existing reading about this topic highlights the urgent need for international cooperation and a renewed focus on strengthening and clarifying existing legal principles governing weather modification in warfare. As cloud seeding and other weather modification technologies continue to advance, it is crucial to establish a comprehensive legal framework that can address the unique challenges that come with these technologies in military contexts. This study aims to contribute to this goal by identifying key areas for legal development and proposing solutions to fill the current regulatory void surrounding cloud seeding in warfare.

Theoretical Framework

For the purpose of the discussion in this paper, we will be using two relevant theoretical frameworks to gain valuable insights, namely International Regime Theory and the Precautionary Principle. These frameworks offer different but complementary perspectives on how to approach the issue of regulating weather modification technologies in a military context.

International Regime Theory, as articulated by scholars like Krasner (1983) and Young (1989), focuses on how states cooperate to address shared problems through sets of principles, norms, rules, and decision-making procedures[24]. In the context of cloud seeding, this theory helps explain the challenges in creating effective international regulations. For example, the ENMOD Convention represents a partial regime addressing environmental modification techniques, but its effectiveness is limited by factors such as rule clarity, consensus among states, and enforcement mechanisms. Recent scholarship has expanded on these ideas. Brunnée and Toope (2010) argue that regime effectiveness is enhanced by perceived legitimacy, stemming from inclusive processes, fair rules, and adaptability[25]. Considering that technologies like cloud seeding have both beneficial and potentially harmful applications, as a result creating effective regulatory frameworks for such dual-use technologies is challenging.[26]

The Precautionary Principle, prominent in international environmental law since the 1990s, advocates for precautionary measures when an activity threatens harm to human health or the environment, even if cause-and-effect relationships are not fully established.[27]This principle is a tool for navigating uncertainty in the face of potential environmental harm. While it advocates for proactive measures to protect public health and the environment, striking a balance is crucial. Overly stringent applications can stifle innovation and economic growth.[28] Conversely, a weak interpretation may fail to safeguard against significant risks. Ultimately, the principle should be informed by robust, independent scientific assessment to prevent the manipulation of evidence.[29]

The Precautionary Principle aligns with recent developments in international environmental law,

[24]Brahm, E. (2016, July 12). International Regimes. Retrieved August 13, 2024, from *Beyond Intractability website*: <https://www.beyondintractability.org/essay/international_regimes>

[25]Brunnée, J., and Toope, S. J. (2010). Legitimacy and Legality in International Law. *Cambridge University Press*.

[26]Selgelid, M. J. (2009). Governance of dual-use research: an ethical dilemma. *Bulletin of the World Health Organization, 87(9),* 720–723. <https://doi.org/10.2471/blt.08.051383>

[27] Wingspread Conference on the Precautionary Principle — The Science and Environmental Health Network. (2013, August 5). The Science and Environmental Health Network. Retrieved from *The Science and Environmental Health Network website*: <https://www.sehn.org/sehn/wingspread-conference-on-the-precautionary-principle>

[28] Stirling, A. (2016). Precaution in the Governance of Technology. *SSRN Electronic Journal.*<https://doi.org/10.2139/ssrn.2815579>

[29] Peel, J. (2005). The precautionary principle in practice: environmental decision-making and scientific uncertainty (pp. 222–225). *Sydney: Federation Press.*

such as the Paris Agreement on climate change.[30]Which incorporates precautionary approaches to prevent irreversible damage to the climate system. This precedent could provide a basis for applying similar principles to the regulation of weather modification technologies.

International regime theory provides insights into the political and institutional dynamics of creating effective international regulations, while the precautionary principle offers a normative guide for decision-making in the face of scientific uncertainty and potential severe harm. Together, these frameworks can help the development of more comprehensive and effective international legal instruments to govern the use of weather modification technologies in military contexts, balancing the need for regulation with the complexities of international cooperation and scientific uncertainty.

Methodology

The methodology for this analysis relies primarily on historical case studies and recent developments in weather modification technologies, with a focus on their potential military applications. Due to the often-classified nature of such programs, publicly available information is limited. However, declassified documents, existing analyses, and recent statements provided some level of insights into the development, use, and implications of weather modification technologies in a military context.

USA's Operation Popeye

The United States' "Operation Popeye," conducted during the Vietnam War, serves as a critical historical case study for understanding the military application of weather modification technologies. This covert cloud seeding program, operational from 1967 to 1972, aimed to extend the monsoon season in Southeast Asia, particularly over the Ho Chi Minh Trail. The primary objective was to impede enemy logistics through increased rainfall and muddy conditions, effectively using weather as a weapon of war[31]. Operation Popeye represents one of the first known large-scale attempts to use weather modification as a military tactic. The program

[30] UNFCCC. (2022). Key aspects of the Paris agreement. Retrieved August 13, 2024, from *UNFCCC website:*<https://unfccc.int/most-requested/key-aspects-of-the-paris-agreement#:~:text=The%20Paris%20Agreement>

[31]Hersh, S. M. (1972, July 3). Rainmaking Is Used As Weapon by U.S. *The New York Times.* Retrieved from <https://www.nytimes.com/1972/07/03/archives/rainmaking-is-used-as-weapon-by-us-cloudseeding-in-indochina-is.html>

involved aircraft flights that dispersed silver iodide into clouds, aiming to increase precipitation. While the full environmental impact of Operation Popeye remains unclear, its exposure led to significant international concern and debate about the ethics and legality of such operations.

The revelation of Operation Popeye highlighted several key issues that continue to be relevant in discussions of weather modification today. First, it demonstrated the potential for unintended consequences in weather modification efforts. Altering weather patterns, even in a localized area, can have far-reaching effects that are difficult to predict or control. Second, the program underscored the challenges in distinguishing between civilian and military applications of weather modification technology. The same techniques used for benign purposes like drought mitigation could potentially be weaponized, blurring the lines between peaceful and hostile uses. Perhaps most significantly, Operation Popeye led to increased international awareness of the need for oversight and regulation of weather modification technologies. The program's exposure was a key factor in the development of the Environmental Modification Convention (ENMOD), which prohibits the military or hostile use of environmental modification techniques.[32]

China's Weather Modification Program

Unlike the covert nature of Operation Popeye, China's contemporary weather modification program provides a case study in the open pursuit of large-scale weather alteration capabilities. In 2020, China announced ambitious plans to expand its weather modification system to cover an area of 5.5 million square kilometers by 2025. This program, while ostensibly for civilian purposes such as drought mitigation and hail suppression, has raised concerns among neighboring countries, particularly India. China's weather modification efforts are notable for their scale and sophistication. The program involves the deployment of a vast network of fuel-burning chambers on Alpine slopes, particularly in the Tibetan Plateau region. These chambers are designed to release silver iodide particles into the atmosphere, promoting cloud formation

[32]Ishfaq, S. (2022, September 10). Environmental Modification – A War Without Weapons. Retrieved August 11, 2024, from *Paradigm Shift website*: <https://www.paradigmshift.com.pk/war-with>

and precipitation. According to reports, more than 500 such burners have been deployed across Tibet, Xinjiang, and other areas.[33]

The Chinese program has already demonstrated its capabilities in several high-profile events. During the 2008 Beijing Olympics, cloud seeding was reportedly used to ensure clear skies for the opening ceremony[34]. Similar techniques were employed during the 2022 Winter Olympics. These demonstrations highlight the potential effectiveness of weather modification technologies, but also raise questions about their broader implications. China's weather modification activities have not gone unnoticed by its neighbors. India, in particular, has expressed concerns about the potential impact of these activities on its own weather patterns and water resources. Indian Defence Minister Rajnath Singh has publicly stated that climate change in certain border states may be related to national security, hinting at concerns over China's weather modification activities.[35]

Comparative Analysis of USA and China's Weather Modification

The comparison between Operation Popeye and China's current weather modification program reveals significant shifts in the approach to and perception of weather modification technologies over several decades. While Operation Popeye was a localized, explicitly military effort focused on Southeast Asia, China's program aims for much broader coverage, potentially affecting weather patterns across a vast region including parts of neighboring countries. This expansion in scale underscores the potential for weather modification to have far-reaching, cross-border impacts. The stated purposes of these programs also differ markedly. Operation Popeye was designed to gain tactical military advantage, whereas China frames its efforts as primarily civilian, addressing issues like drought and agricultural productivity. However, the dual-use nature of weather modification technology blurs the line between civilian and military applications. China's program benefits from decades of scientific progress since Operation

[33]Jash, A. (2024, March 15). Is China modifying the weather? India has concerns. Retrieved August 11, 2024, from orfonline.org website: <https://www.orfonline.org/expert-speak/is-china-modifying-the-weather-india-has-concerns>

[34] Li H, Dai Y, Wang H, Cui J. Artificial seeding effects of convective clouds on the opening day of Beijing 2008 Summer Olympics. J Geosci Environ Prot. 2017;5(4):118-138. doi:10.4236/gep.2017.54010

[35]Jash, A. (2024, March 15). Is China modifying the weather? India has concerns. Retrieved August 11, 2024, from orfonline.org website: <https://www.orfonline.org/expert-speak/is-china-modifying-the-weather-india-has-concerns>

Popeye, with advances in meteorology, cloud physics, and delivery systems likely increasing the effectiveness and precision of weather modification techniques. This technological progression amplifies both the potential benefits and risks associated with weather modification.

Both programs have triggered international concern, but the nature of these concerns has evolved. Operation Popeye led to immediate calls for international regulation, resulting in agreements like ENMOD. China's activities, while not explicitly military, have prompted diplomatic tensions and security concerns, particularly with India, reflecting the growing recognition of weather modification as a potential security issue, even when not overtly militarized. Perhaps the most striking difference lies in transparency. Operation Popeye was a classified program, only revealed years after its implementation while China's program, while not fully transparent, is much more open about its existence and general aims. This openness, however, has not fully allayed international concerns about the program's potential impacts and intentions, highlighting the complex challenges surrounding the development and use of weather modification technologies in the modern era.

Legal Implications

The case studies of Operation Popeye and China's weather modification program highlight several potential dangers and legal considerations that remain relevant today. Large-scale weather modification could have far-reaching and unpredictable effects on ecosystems and climate patterns. The Intergovernmental Panel on Climate Change has noted that techniques like cloud brightening, while potentially effective in reflecting solar radiation, could significantly impact regional weather patterns and the ozone layer [36]. Weather systems do not respect national boundaries, raising concerns about unintended impacts on neighboring countries. India's apprehensions about China's weather modification activities in Tibet illustrate this issue. The potential for weather modification to affect water resources, agriculture, and local climate in neighboring regions presents a significant challenge to international relations and security. The historical use of weather modification as a weapon, as demonstrated by Operation Popeye, remains a significant concern. While current programs may be civilian in nature, the potential for

[36]Raczek T. Geoengineering: Reining in the weather warriors. *Chatham House – International Affairs Think Tank.* February 15, 2022. Accessed August 13, 2024. <https://www.chathamhouse.org/2022/02/geoengineering-reining-weather-warriors>

weaponisation cannot be ignored. The difficulty in distinguishing between civilian and military applications of this technology complicates efforts to prevent its hostile use.

The primary international agreement governing weather modification is the ENMOD Convention, which prohibits the military or hostile use of environmental modification techniques. However, this agreement has limitations. For instance, China is not a full signatory, having only agreed to apply the convention to Hong Kong and Macau.[37] Furthermore, the convention's focus on military use may not adequately address the security implications of large-scale civilian weather modification programs.

One of the most significant hurdles in regulating weather modification is the difficulty in verifying compliance with international agreements. Distinguishing between natural weather events and those induced by human intervention is extremely challenging, complicating efforts to enforce any prohibitions on weather modification for military purposes. These case studies highlight the complex interplay between scientific advancement, military strategy, and international law in weather modification. They underscore the urgent need for updated international agreements and transparent dialogue to address the potential risks and ethical concerns associated with these technologies. As weather modification capabilities continue to improve, the international community faces the challenge of balancing the potential benefits of these technologies with the need to prevent their misuse and mitigate their potential negative impacts on global security and the environment.

Discussion of Findings

This study has explored the ethical and legal predicament surrounding cloud seeding as a potential war strategy. The findings reveal a complex landscape characterized by legal ambiguity, ethical concerns, and an urgent need for standardized international regulations. The absence of clear international regulations governing cloud seeding in warfare creates a dangerous vulnerability in the global legal framework. Existing legal instruments, such as the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD), The Hague Conventions (1907), and the Geneva Conventions (1949),

[37] United Nations Treaty Collections. Convention on the prohibition of military or any other hostile use of environmental modification techniques. 10 December 1976. Available at: https://treaties.un.org/Pages/ViewDetails.aspx?src=INDandmtdsg_no=XXVI-1andchapter=26andclang=_en>

offer fragmented and potentially subjective protections. This legal ambiguity increases the risk of nations resorting to cloud seeding technology in conflicts, exploiting the lack of explicit prohibitions.[38] To address this gap, several potential avenues for establishing standardized laws have been identified. One approach involves expanding the ENMOD Convention to explicitly include cloud seeding within the scope of prohibited environmental modification techniques. This would require defining clear criteria for assessing the "widespread, long-lasting, or severe effects" in the context of weather modification. Additionally, establishing more robust verification and compliance mechanisms would be crucial to ensure the treaty's effectiveness in regulating cloud seeding activities.

Another option is to clarify existing international law by reinterpreting treaties to encompass cloud seeding. This could involve applying the Hague Convention's prohibition on "wanton destruction" (Art. 23(g)) to the potential environmental damage caused by cloud seeding. Similarly, interpreting the Geneva Convention's Protocol I regarding "widespread, long-lasting or severe damage to the natural environment" (Art. 55(1)) to include the effects of weather modification could provide additional legal grounds for regulation. However, this approach would require international legal consensus and potentially the development of new protocols or interpretations.

Interestingly, developing a dedicated international treaty specifically addressing cloud seeding use especially in warfare could provide the most comprehensive solution. Such a treaty could clearly define cloud seeding technology and its various applications, outlining permissible and prohibited uses in both peacetime and wartime contexts. It would also establish robust enforcement mechanisms and penalties for violations, creating a framework for international cooperation in monitoring and regulating cloud seeding activities. The ethical implications of cloud seeding in warfare are significant and must be carefully considered. The indiscriminate nature of weather modification challenges the principle of distinction in international

[38] Mulder A. The legal frameworks for cloud seeding: navigating international regulations. *Corax Foundation*. Published May 15, 2023. Accessed May 1, 2024. <https://coraxfoundation.com/2023/05/15/the-legal-frameworks-for-cloud-seeding-navigating-international-regulations>

humanitarian law, making it difficult to limit effects to military targets[39]. For instance, inducing rainfall to flood enemy supply routes could lead to widespread civilian displacement and agricultural disruption in the targeted region and beyond. This raises serious concerns about proportionality and the ability to conduct cloud seeding operations in compliance with the laws of war.

The potential for cloud seeding to contribute to or intensify climate change adds another layer of ethical complexity to the use of weather modification in warfare. Scientific uncertainty regarding the long-term effects of large-scale cloud seeding compounds the ethical dilemma. The precautionary principle in environmental ethics suggests that in the face of such uncertainty, we should err on the side of caution and avoid actions that could cause severe or irreversible harm. The complexity of global weather systems means that even well-intentioned cloud seeding operations could have unforeseen ripple effects across vast geographic areas. Addressing the key questions surrounding the regulation of cloud seeding in warfare requires a multifaceted approach. Updating international law to effectively address the unique challenges presented by military applications of cloud seeding must consider the potential for unintended environmental consequences. This could involve developing specific protocols within existing frameworks or creating new legal instruments that explicitly address weather modification techniques. Establishing mechanisms to monitor and verify compliance with regulations is crucial, given the difficulties in attributing weather events to intentional manipulation. This could involve the creation of an international body responsible for monitoring weather patterns and investigating potential violations. Advanced technologies, such as satellite imagery and atmospheric sensors, could be employed to detect unusual weather patterns or the presence of cloud seeding agents.

Realistically, addressing the ethical concerns surrounding cloud seeding in warfare requires an all-encompassing framework for assessing the potential risks and benefits of these technologies which should include the development of international guidelines for the responsible use of weather modification techniques, incorporating principles of environmental stewardship and respect for civilian populations. Addressing these issues requires a collaborative international

[39] Protocol Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977. Art. 48. 2022. Available from: <<https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-48>. Accessed August 13, 2024.

effort to develop comprehensive legal frameworks, establish effective monitoring mechanisms, and navigate the ethical implications of weather modification technologies.

Recommendations

To address the identified legal and ethical challenges surrounding cloud seeding in warfare, we propose the following comprehensive recommendations focusing on the establishment of legal instruments, policy development, enforcement mechanisms, and responsible deployment of the technology:

Strengthening International Legal Frameworks

Expanding the ENMOD Convention is the most important step to explicitly include cloud seeding within its scope. This expansion should clearly define cloud seeding techniques and establish specific criteria for assessing "widespread, long-lasting, or severe effects" in the context of weather modification. Simultaneously, developing a dedicated treaty specifically addressing cloud seeding in both military and civilian contexts is necessary. This treaty should define permissible and prohibited uses of cloud seeding technology, establish clear guidelines for environmental impact assessments, outline mechanisms for international cooperation and information sharing, and set penalties for violations and procedures for dispute resolution. Additionally, clarifying existing international humanitarian law, such as the Hague and Geneva Conventions, to explicitly cover weather modification techniques is essential. This could involve developing additional protocols or interpretative guidelines that apply principles of proportionality and distinction to cloud seeding activities.

Enhancing Policy and Governance Structures

Establishing an international oversight body is equally important to effectively govern cloud seeding activities globally. This body would be responsible for monitoring compliance with international regulations, conducting investigations into alleged violations, facilitating information exchange between nations, and providing technical assistance and capacity building for developing countries. Implementing a global registry of cloud seeding activities is also crucial, requiring all nations to report planned and ongoing weather modification operations. This registry should include detailed information on the purpose, scope, and duration of cloud

seeding activities, environmental impact assessments and risk mitigation strategies, and regular updates on the progress and outcomes of operations.

Furthermore, establishing notification protocols is essential, creating a mandatory system for prior notification of cloud seeding activities, especially those that may have transboundary effects. This system should require nations to inform neighboring countries before conducting cloud seeding operations, establish clear communication channels for addressing concerns and resolving disputes, and set timelines for notification and response procedures.

Strengthened Enforcement Mechanisms

Developing robust verification protocols is essential for ensuring compliance with cloud seeding regulations. These protocols should include regular inspections of cloud seeding facilities and equipment, satellite monitoring of weather patterns and atmospheric conditions, and analysis of environmental data to detect anomalies potentially related to weather modification. Creating a sanctions framework is equally important, involving a transparent system of sanctions for violations of cloud seeding regulations. This framework should include economic penalties for minor infractions, restrictions on access to weather modification technologies for repeated violations, and referral to international judicial bodies for severe breaches. Enhancing attribution capabilities is also crucial, requiring investment in technologies and methodologies to improve the ability to attribute unusual weather events to intentional manipulation. This will require some advanced technology capability as well as data sharing and analysis networks.

Promoting Ethical Considerations

Designing well laid out ethical guidelines for the use of cloud seeding technology is essential. These guidelines should address principles of environmental responsibility and intergenerational justice, respect for national sovereignty and territorial integrity, and considerations of proportionality and distinction in military applications. Establishing transparency measures is equally important, implementing mechanisms to ensure transparency in cloud seeding activities. This should include regular public reporting on weather modification operations, open access to environmental impact assessments and research findings, and engagement with civil society organizations and affected communities. Promoting international dialogue is also crucial,

facilitating ongoing discussions among nations, experts, and stakeholders on the ethical implications of weather modification through regular international conferences and forums, collaborative research initiatives, and engagement with diverse perspectives, including from developing countries and vulnerable populations.

Capacity Building and Education

Organising training programs for policymakers and legal professionals on the legal and ethical aspects of cloud seeding is essential. These programs should cover international law and regulations governing weather modification, environmental impact assessment methodologies, and ethical decision-making frameworks for deploying cloud seeding technology. Enhancing public awareness is equally important, implementing public education initiatives to inform citizens about cloud seeding technologies and their potential impacts. This should include educational materials for schools and universities, public awareness campaigns through media and social platforms, and community engagement programs in areas potentially affected by cloud seeding activities.

Implementing the above-listed recommendations will enable the international community to establish a framework for governing the use of cloud seeding technology. This approach balances the potential benefits of weather modification with the need to protect the environment, respect national sovereignty, and maintain global security. Considering the level of development in the cloud seeding space, evolving legal and policy frameworks will be crucial to address emerging challenges and ensure the responsible deployment of this powerful technology.

Conclusion

Cloud seeding technology presents a complex challenge, offering potential benefits while raising significant ethical and legal concerns in both military and civilian applications. This paper has focused primarily on military uses, but it's crucial to recognize that even civilian deployment of cloud seeding could lead to misinterpretation and conflict if not properly regulated and communicated. The ability to manipulate weather patterns is a double-edged sword, offering tactical advantages in warfare but raising profound ethical questions and legal ambiguities. The absence of clear international regulations creates a dangerous gray area, increasing the risk of

misuse and unintended consequences. Ethical concerns surrounding cloud seeding are undeniable. Disrupting weather patterns, even with benign intentions, could have far-reaching environmental consequences, potentially harming civilians and ecosystems across borders. The long-term impact on ecological balances remains a significant cause for alarm.

The legal landscape is fragmented and inadequate, with existing international treaties offering only piecemeal protections. This lack of clear legal boundaries hinders accountability for potential misuse or unintended consequences. Urgent international cooperation is needed to develop comprehensive regulations governing both military and civilian uses of cloud seeding. Policymakers, military strategists, and international organizations must work together to establish oversight mechanisms, promote responsible governance, and foster dialogue between nations. Without concerted action and comprehensive regulation, the destructive potential of weather manipulation whether intentional or unintended, military or civilian could become an unavoidable reality. The international community must work together to harness the benefits of cloud seeding while mitigating its risks, ensuring this powerful technology serves humanity rather than becoming a source of conflict or environmental degradation.