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In What Ways Might Physical Tipping Points in the Climate System Pose 'Security' Problems Now and in the Future?

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Abstract: This paper analyzes physical tipping points in the climate system and their implications for national security, food security and social stability. Physical tipping points are critical states in the climate system that, once passed, lead to irreversible, rapid, and self-accelerating changes. Major tipping points include melting glaciers and rising sea levels, the collapse of terrestrial ecosystems, and an increase in the frequency and intensity of climate extremes. The paper explores the far-reaching impact of these tipping points on security issues, proposes countermeasures and policy recommendations by analyzing the case of Arctic climate change on Russian security, and emphasizes the importance of interdisciplinary cooperation and policy responses to reduce the risks posed by climate change.

Keywords: Physical tipping points, climate change, climate security

1. Introduction

In climate science, a physical tipping point usually refers to a point in the climate system beyond which a fundamental and irreversible change occurs. These changes are often rapid and self-accelerating, meaning that once triggered, their process will be difficult to reverse or control through human intervention. Climate change and the physical tipping points therein exhibit a profound and intricate association with security concerns, exerting a significant impact on national security paradigms, food security matrices, and the overarching domain of social stability. The principal tipping points within the climate system can be encapsulated as follows: the melting of glaciers and the consequent rise in sea level, the disintegration of terrestrial ecosystems, and the augmented frequency and enhanced intensity of extreme climatic events. These factors are analyzed in conjunction with national security, food security and social stability to elaborate on the impact of physical tipping points.

Therefore, this paper will analyze the impact of physical tipping points in the climate system on national security, food security and social stability, propose countermeasures and policy recommendations through the analysis of specific realistic cases, and emphasize the importance of interdisciplinary cooperation and policy responses. The structure of the paper is clear and clear. Firstly, the direct definition of physical critical point and its connection with security issues are described. Secondly, the physical critical point and its specific impact on national security, food security and social stability are mainly introduced. Secondly, it mainly introduces the major critical points in the climate system. Subsequently, it predominantly elaborates on the manifold repercussions

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of climate change upon security issues from the perspectives of national security dimensions, food security landscapes, and the realm of social stability. Then, the impact of climate change in the Arctic region on the security of Russia is analyzed as a case study, countermeasures and policy suggestions are proposed according to the current climate problems, and finally, the impact of physical turning points in the climate system on security issues is summarized, emphasizing the importance of interdisciplinary cooperation and policy responses.

2. Physical Tipping Points

Milkoreit et al. [1] defined the critical point as a special point in the nonlinear change process triggered by small quantitative changes in the system, which is impelled by the internal feedback mechanism of the system and inexorably gives rise to qualitative transformations in the system state, with such alterations typically being irreversible. Spaiser et al. [2] posit that a critical juncture emerges when a transformation within a crucial system attains self-sustenance upon surpassing a compelled threshold, thereby engendering qualitative alterations in the state of the system, which are actuated by one or more positive/amplifying feedback circuits. Tipping points encompass a multiplicity of forms of transformation, spanning from extensive-scale modifications in the environment and ecology to particular physical or chemical alterations. Anthropogenically-induced climate change is prone to propel several large-scale "critical determinants" towards tipping points. Critical factors comprise the irreversible ablation of the Greenland ice sheet, the desiccation of the Amazon rainforest, the perturbation in the West African monsoon regime, and the attenuation or cessation of the Atlantic Meridional Overturning Circulation [3]. Upon the attainment of a critical threshold in the melting process of Greenland's ice sheet, an irreversible depletion of the ice sheet will ensue, thereby precipitating an accelerated elevation in sea level. This, in turn, imperils the security of coastal metropolises and low-lying nations, and potentially instigates large-scale demographic displacement as well as a plethora of socio-economic conundrums.

3. Major tipping points in the climate system

3.1. Glacier Melting and Sea Level Ascension

Glacier melting and sea level elevation are recognized as prominent tipping points within the context of climate change. The depletion of the Greenland and Antarctica ice sheets constitutes a substantial proportion of the global sea level increment. This depletion is attributable, in part, to the ramifications of escalating temperatures and, in part, to the augmented ocean temperatures to which these ice sheets are subjected [4]. As per the data from the IPCC [5], a severe elevation in ocean temperatures has been observed. Ocean warming is responsible for 91% of the heat gain within the climate system. In contrast, land warming, ice loss, and atmospheric warming contribute approximately 5%, 3%, and 1%, respectively. Nevertheless, further temperature augmentation will precipitate more recurrent and intensified marine heat waves. The sea level rise ensuing from glacier melting endangers the ecological integrity of island nations and coastal regions. According to NASA [6], the Greenland ice sheet is experiencing an annual ice loss of around 27.9 billion tons, which represents a sixfold increase compared to the rate of ice loss in the 1990s. Collectively, the two major ice sheets (Greenland and Antarctica) had an annual loss of 81 billion tons in the 1990s, whereas this figure soared to 475 billion tons per year in the 2010s, signifying a sixfold escalation.

3.2. Collapse of terrestrial ecosystems

The collapse of terrestrial ecosystems has an important impact on biodiversity and ecological functions. Some scholars have found that changes in ecosystems reduce local species richness and

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ecological complexity, especially in tropical regions, emphasizing the key role of land management in biodiversity conservation [7]. The collapse of terrestrial ecosystems is a serious threat to human security, The Guardian [8] reports on Australia's bushfires, which have killed at least 33 people and destroyed thousands of homes, broke out after a long drought.

3.3. Amplification of the Occurrence Frequency and Severity of Climate Extremes

The augmentation in the frequency and intensity of climate extremes represents a crucial tipping point within the framework of climate change, exerting profound and far-reaching impacts not solely upon natural ecosystems but also on the structures of human society and economy. With the escalation of global average temperatures, the frequency and potency of extreme weather phenomena such as heatwaves, droughts, torrential rainfall, and hurricanes have been on the rise. Long-term observational data suggest a marginal increment in the intensity and growth rate of tropical cyclones on a global scale, accompanied by a more pronounced positive trend in the North Atlantic [9]. In addition to the occurrence of heatwaves, Europe has witnessed catastrophic flooding events as reported by CNN [10]. In Western Europe, at least 54 individuals have perished due to severe flooding, with as many as 70 people unaccounted for and 49 fatalities in Germany, six deaths in Belgium, and Luxembourg and the Netherlands also being adversely affected subsequent to the onslaught of flash floods across the western and southern regions of the continent, which has led to the collapse of numerous edifices.

4. Multiple security implications of climate change

4.1. National Security

In the context of global climate warming, the melting of glaciers induces an elevation in sea levels, thereby subjecting island nations and coastal regions to severe jeopardy. Sea level rise gives rise to a series of consequences, including the loss of land and coastal erosion, an augmented frequency and intensity of coastal flooding attributable to tides, storms, and waves, as well as an enhanced salinization of coastal aquifers. These phenomena, in turn, lead to the contraction of habitats, alterations in the geographical distribution of coastal species, and a diminution of biodiversity [11]. For island countries and coastal regions that rely on Marine and coastal tourism, land loss and ecosystem degradation from sea level rise can seriously impact their economic development, while frequent flooding and storm surges increase the cost of infrastructure maintenance and rehabilitation. The socio-economic ramifications of disasters precipitated by sea level rise encompass a multiplicity of aspects. These include the loss of human lives, the devastation and demolition of infrastructure, the impairment of agricultural and other economic sectors, the disruption of human activities and services, and an augmented overall exposure and vulnerability of individuals, enterprises, and infrastructure [12]. Vousdoukas et al. [13] demonstrated that within the context of small island developing States, the projected increment in the number of individuals affected by coastal flooding is anticipated to range from 4.5 to 7 times by 2100. This is equivalent to 1.2 - 2.0% of the regional population. Concomitantly, the associated losses are estimated to span from US $6.6 million to US $10.7 billion over the same temporal interval. The economic losses in the Maldives ranged from 9.2% to 12.5%. To avoid being affected by disasters, human beings are forced to rob resources and migrate populations, resulting in climate refugees in a large number of areas, which is easy to trigger inter-regional conflicts and threaten the security of island countries and coastal areas.

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4.2. Food Security

The influence of climate change on agricultural productivity and food security is of a multifarious nature, principally manifested in the aspects of crop growth patterns, the impacts of extreme weather events, as well as the prevalence of pests and diseases. In terms of crop growth, rising temperatures will shorten the growth cycle of crops. Zhao et al. [14] ascertained that, concomitant with the elevation in temperature, the global average yields of wheat, corn, soybean, and rice are projected to decline by 6%, 7.4%, 3.1%, and 3.2%, respectively. The increase in temperature reduces the growth cycle of crops and reduces the photosynthetic time. Rising temperatures will lead to a decline in food production. With respect to extreme weather phenomena and the prevalence of pests and diseases, agricultural production within food-insecure regions is imperiled by climate change, with Asian countries being particularly susceptible. A diverse array of climate-induced extreme events, such as droughts, heatwaves, erratic and intense rainfall regimes, storms, floods, and newly emerging pests, have detrimentally impacted the livelihoods of farmers [15]. Natural disasters constituted the predominant factor contributing to losses in agricultural productivity (encompassing crops and livestock) in Asia. These disasters included extreme temperatures, storms, and wildfires (accounting for 23%), floods (37%), droughts (19%), and pest and animal disease outbreaks (9%), with the cumulative economic toll reaching $1 billion [16]. The occurrence of extreme weather events and the incursion of pests and diseases compound the economic burden borne by farmers.

4.3. Social Stability

The nexus between climatic extremes and social unrest represents a convoluted interplay that encompasses environmental, economic, and political dimensions. In terms of resource scarcity, droughts and floods caused by climate change can easily lead to severe shortages of water and food supplies, and the reduction of such resources can exacerbate social inequalities and lead to conflict and violence. Brzoska and Frohlich [17] posit that climate change will precipitate resource scarcity, which subsequently will give rise to migratory movements and violent confrontations. In terms of political and economic activity, the direct impact of extreme weather events on economic activity can increase unemployment, reduce living standards and increase social instability. In addition to the domain of economic activity, climate-induced disasters impinge directly upon individuals irrespective of their political affiliations and are not circumscribed by the political boundaries delineated on maps. Climate-related issues serve as a nexus, interconnecting specific concerns among communities embroiled in conflict [18]. Climate change could lead to serious social unrest and conflict. The crisis in Syria's northeast Jazira region was triggered by an unprecedentedly severe drought that would have been much less likely to have occurred without global anthropogenic climate change, a severe drought that led to multiple crop failures, leading to mass migration and exacerbating the outbreak of conflict [19].

5. Conclusion

Physical tipping points in the climate system have important security implications, particularly in terms of national security, food security and social stability. On the national security front, climate change, resource shortages, and mass migration will exacerbate tensions between regions and countries, while unstable political environments can easily be exploited by terrorism, exacerbating global security crises. In the context of food security, the elevation of temperatures will have an impact on the growth cycle and productivity of crops. This is liable to result in food shortages and disruptions within the supply chain. Additionally, it will exacerbate the proliferation of pests and diseases, thereby endangering the growth of crops. In the realm of social stability, extreme weather events induced by climate change possess the propensity to intensify the eruption of conflicts and

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contradictions, thereby precipitating social unrest. Climate change is a complex global issue involving environmental science, engineering, economics, sociology, political science and other fields, interdisciplinary cooperation can integrate knowledge and skills in these fields to develop more effective adaptation and mitigation strategies. At the same time, Climate change policy needs to be synergistic with other policy areas. The uncertainty of climate change requires a high degree of flexibility and adaptability in policy to adapt to new scientific findings and technological advances. The implementation of interdisciplinary cooperation and comprehensive policy responses is therefore necessary and a key factor in successfully achieving climate adaptation and mitigation goals.

References

[1] *Milkoreit, M., Hodbod, J. (orcid:---), Baggio, J., Benessaiah, K., Calderon-Contreras, R., Donges, J., Mathias, J.-D., Rocha, J., Schoon, M. and Werners, S. 2018. Defining tipping points for social-ecological systems scholarship-an interdisciplinary literature review.*

[2] *Spaiser, V., Juhola, S., Constantino, S. M., Guo, W., Watson, T., Sillmann, J., Craparo, A., Basel, A., Bruun, J. T., Krishnamurthy, K., Scheffran, J., Pinho, P., Okpara, U. T., Donges, J. F., Bhowmik, A., Yasseri, T., Safra de Campos, R., Cumming, G. S., Chenet, H., Krampe, F., and Abrams, J. F.2023: Negative Social Tipping Dynamics Resulting from and Reinforcing Earth System Destabilisation, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1475.*

[3] *Lenton, T.M. 2011. Early warning of climate tipping points. Nature climate change. 1(4), pp.201–209.*

[4] *Shepherd, A., Ivins, E.R., Geruo A, Barletta, V.R., Bentley, M.J., Bettadpur, S., Briggs, K.H., Bromwich, D.H., Forsberg, R., Galin, N., Horwath, M., Jacobs, S., Joughin, I., King, M.A., Lenaerts, J.T.M., Li, J., Ligtenberg, S.R. M., Luckman, A., Luthcke, S.B., McMillan, M., Meister, R., Milne, G., Mouginot, J., Muir, A., Nicolas, J.P., Paden, J., Payne, A.J., Pritchard, H., Rignot, E., Rott, H., Sørensen, L.S., Scambos, T.A., Scheuchl, B., Schrama, E.J.O., Smith, B., Sundal, A.V., van Angelen, J.H., van de Berg, W.J., van den Broeke, M.R., Vaughan, D.G., Velicogna, I., Wahr, J., Whitehouse, P.L., Wingham, D.J., Yi, D., Young, D. and Zwally, H.J. 2012. A Reconciled Estimate of Ice-Sheet Mass Balance. Science (American Association for the Advancement of Science). 338(6111), pp.1183–1189.*

[5] *IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647*

[6] *Jet Propulsion Laboratory. NASA. 2020.Greenland, Antarctica Melting Six Times Faster Than in the 1990s [Online]. [Accessed 16 May 2024]. Available from: https://www.nasa.gov/centers-and-facilities/jpl/greenland-antarctica-melting-six-times-faster-than-in-the-1990s/*

[7] *Newbold, T., Hudson, L.N., Hill, S.L.L., Contu, S., Lysenko, I., Senior, R.A., Börger, L., Bennett, D.J., Choimes, A., Collen, B., Day, J., De Palma, A., Díaz, S., Echeverria-Londoño, S., Edgar, M.J., Feldman, A., Garon, M., Harrison, M.L.K., Alhusseini, T., Ingram, D.J., Itescu, Y., Kattge, J., Kemp, V., Kirkpatrick, L., Kleyer, M., Correia, D.L.P., Martin, C.D., Meiri, S., Novosolov, M., Pan, Y., Phillips, H.R.P., Purves, D.W., Robinson, A., Simpson, J., Tuck, S. L., Weiher, E., White, H.J., Ewers, R.M., Mace, G.M., Scharlemann, J.P.W. and Purvis, A. 2015. Global effects of land use on local terrestrial biodiversity. Nature (London). 520(7545), pp.45–50.*

[8] *The Guardian. 2020.Interactive map: which areas of Australia were hit by multiple disasters in 2020? [Online]. [Accessed 16 May 2024]. Available from: https://www.theguardian.com/news/datablog/2020/dec/22/interactive-map-which-areas-of-australia-were-hit-by-multiple-disasters-in-2020*

[9] *Knutson, T. R., Chung, M. V., Vecchi, G., Sun, J., Hsieh, T-L. and Smith, A. J. P., 2021: Science Brief Review: Climate change is probably increasing the intensity of tropical cyclones. In: Critical Issues in Climate Change Science. pp.1-8 https://doi.org/10.5281/zenodo.4570334*

[10] *Melissa Mahtani, Melissa Macaya, Meg Wagner, Fernando Alfonso III and Veronica Rocha, CNN. 2021. What we know about the deadly flooding in Europe [Online]. [Accessed 16 May 2024]. Available from: https://edition.cnn.com/europe/live-news/deadly-flooding-in-europe-07-15-21/index.html*

[11] *Martyr-Koller, R., Thomas, A., Schleussner, C.-F., Nauels, A. and Lissner, T. 2021. Loss and damage implications of sea-level rise on Small Island Developing States. Current opinion in environmental sustainability. 50, pp.245–259.*

[12] *Cavanagh, R.D., Trathan, P.N., Hill, S.L., Melbourne-Thomas, J., Meredith, M.P., Hollyman, P., Krafft, B.A., MC Muelbert, M., Murphy, E.J., Sommerkorn, M., Turner, J. and Grant, S.M. 2021. Utilising IPCC assessments to support the ecosystem approach to fisheries management within a warming Southern Ocean. Marine policy. 131, pp.104589-.*

DOI: 10.54254/2753-8818/81/2025.19749

[13] *Vousdoukas, M.I., Athanasiou, P., Giardino, A., Mentaschi, L., Stocchino, A., Kopp, R.E., Menéndez, P., Beck, M. W., Ranasinghe, R. and Feyen, L. 2023. Small Island Developing States under threat by rising seas even in a 1.5 °C warming world. Nature sustainability. 6(12), pp.1552–1564.*

[14] *Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D.B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J.-L., Elliott, J., Ewert, F., Janssens, I.A., Li, T., Lin, E., Liu, Q., Martre, P., Müller, C., Peng, S., Peñuelas, J., Ruane, A.C., Wallach, D., Wang, T., Wu, D., Liu, Z., Zhu, Y., Zhu, Z. and Asseng, S. 2017. Temperature increase reduces global yields of major crops in four independent estimates. Proceedings of the National Academy of Sciences - PNAS. 114(35), pp.9326–9331.*

[15] *Habib-ur-Rahman, M., Ahmad, A., Raza, A., Hasnain, M.U., Alharby, H.F., Alzahrani, Y.M., Bamagoos, A.A., Hakeem, K.R., Ahmad, S., Nasim, W., Ali, S., Mansour, F. and EL Sabagh, A. 2022. Impact of climate change on agricultural production; Issues, challenges, and opportunities in Asia. Frontiers in plant science. 13, pp.925548–925548.*

[16] *McGuire, S. 2015. FAO, IFAD, and WFP. The State of Food Insecurity in the World 2015: Meeting the 2015 International Hunger Targets: Taking Stock of Uneven Progress. Rome: FAO, 2015. Advances in nutrition (Bethesda, Md.). 6(5), pp.623–624.*

[17] *Brzoska, M. and Fröhlich, C. 2016. Climate change, migration and violent conflict: vulnerabilities, pathways and adaptation strategies. Migration and development (Abingdon, Oxfordshire, UK). 5(2), pp.190–210.*

[18] *Selby, J. 2019. Climate change and the Syrian civil war, Part II : the Jazira's agrarian crisis.*

[19] *Scartozzi, C.M. 2022. Climate-Sensitive Programming in International Security: An Analysis of UN Peacekeeping Operations and Special Political Missions. International peacekeeping (London, England). 29(3), pp.488–521.*