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What are the Impacts of Climate Change on Trade through the Lens of the Panama Canal?

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Abstract

The development and growth of the trade industry brings change to many aspects of the world, but most notably, its connection to changes in climate. Most commonly is harmful emissions of excess greenhouse gases by different vehicles that physically transport goods, most usually that greenhouse gas being CO_2 . Despite research across the world having been done regarding the connection between the specific factors connecting climate change and trade welfare, it is difficult to find the linkage compiled as a cycle that relates those changes back to the initial trade companies. These factors are the relationships between trade infrastructure and environmental change, these changes and climate disasters, and the damages these disasters inflict on the physical systems needed for trade companies to effectively run. It is important that we recognize this cycle not only to avoid damage and potentially dangers, but to also increase trade efficiency as sustainable as possible. This would allow for healthy trade practice to benefit future generations amongst growing change and also better protect future environments and trade. Despite novel methods of emission reduction, the trade industry is a clear example of the pattern observed from the damage on trade's infrastructure caused by climate change that is ultimately caused by the industry itself. Due to that absence of papers discussing this cycle explicitly, or anything remotely similar to it, this paper aims to synthesize all of the different concepts and main takeaways from the countless articles and papers that discuss the different factors within this cycle as a whole. Using literature review, this paper compiles, analyses, and identifies those links and factors. By further using the Panama Canal as evidence of a trade infrastructure that is particularly vulnerable to climate change and disasters, we are able to use its example to the greater cycle being observed. It additionally discusses the key reasons as to why we should allocate attention to these effects. If nothing changes, the implication is that while both trade and climate change keep growing, they cause great changes and potential harm to our economy, trade world, and potentially even society.

Keywords: Climate change, Panama canal, Trade, Infrastructure

1. Introduction

The severity of climate change risk is one of the most uncertain issues and most likely the largest sources of risk for businesses and countries across the world. This is in part because the threat greatly affects trade, among other contributors, which businesses rely on. Not just businesses too, countries can boost their economies by selling goods made on their soil, and by establishing financially beneficial trade relations with other corporations or countries. Improvement, growth, and positive development in trade provide economies with the opportunity to become wealthier and more successful. It is crucial that we acknowledge this, as any risks to this ideal system of economic stability would threaten the daily lives of many. That is why it is imperative we maintain careful care of trade, and potentially unseeming threats, and the vice versa applies as well. We must also ensure that our trade practices are regulated and do not get out of hand. While the positive outcomes of trade are well known, much less is known regarding the negative

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impacts trade has, such as the release of excess greenhouse gases into the atmosphere. There are many papers and sources discussing varying specific relationships between trade and climate change. However, unlike those sources, this paper seeks to synthesise them to conceptualize this two way connection that observes the relationship that ties together the growth of trade companies and their overall output, to ultimate infrastructure damage that harms those very same businesses. This specifically involves the different processes that enable the growth of trade , which then leads to different environmental impacts – most prominently air pollution – which furthermore contributes to the growing amount of environmental and climate change, in turn manifesting as climate disasters and causing damage to different facilities and resources required for these trade maneuvers to normally perform. As years go by, and trade increases and simultaneously so do trade emissions, natural discrepancies due to these climate disasters have an increasingly higher potential to hinder trade. A clear example that directly and most clearly illustrates this phenomena is the Panama Canal. Maritime transport, which is one of the one of the least emission producing means of trade, is at threat of unpredictable water patterns that could very well impact the efficiency of the canal's every day procedures. By breaking down the Panama Canal, we are able to truly dissect and flesh out how this cycle applies to trade as a whole.

Ever since its opening to commerce in 1914, the Panama Canal has proven to be vital within the trade industry as a crucial means of cutting ship routes' lengths and costs.. Aside from the Suez Canal, it holds the role as one of the two most important waterways in maritime trade. Its location effectively serves as a connection between the Atlantic and Pacific oceans that allows goods to be easily transported there and back, and it is recognized as a key connector for international transport. Before the Panama Canal, the tiresome route around the very tip of South America, Cape Horn, was required in order to connect the East and West coasts of the U.S, and any other needed connections that had to go around South and Central America. However thanks to the Panama Canal, a less time consuming and cost-effective alternative was provided, which is very desirable. The most fundamental component for maritime shipping networks lies in transshipment, which the Panama Canal provides. In 2012, trade between the U.S. East Coast and Asia accounted for nearly 39 percent of the cargo going through the canal, while also helping transport goods from the west and east coasts of the U.S. And ever since the emergence of the Panama Canal, ports and other maritime services on either side have benefited with increased traffic.

As shown in Figure 1, one of areas with the highest gains from international trade includes where Panama is. Of course, the entirety of the area's success can't be entirely attributed to the presence of the Panama Canal, yet due to the canal's overall convenient location, it is understandable as to why the percent gross domestic product (GDP) is high. Because in an area where countless vessels transport goods internationally continuously through the canal, there are very high gains from transshipment specifically.

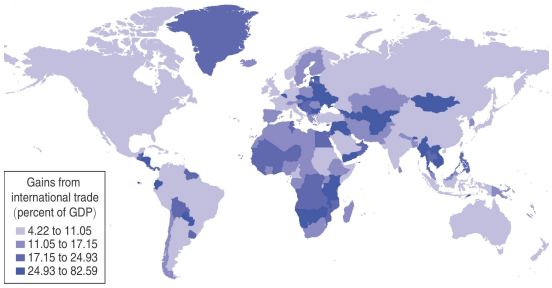

Figure 1. Percent GDP Around the World (Shapiro, 2016).

Although previously being quite useful due to its convenient location, its future expansion in the June of 2016 boosted container throughput immensely, this becoming significantly more valuable than before. With increased container throughput as result of this expansion, the Panama Canal's transshipment capabilities were only greatly benefitted, allowing for an extremely positive response from the transshipment-reliant maritime shipping networks. One key factor for this expansion was due to the difficulty to transport post-Panamax vessels through the canal. This expansion, although incredibly costly, proved to immensely benefit all of the maritime-reliant industries revolving around it.

However, what is behind the scenes of this successful canal? How does it really work? The majority of the canal's 80 km trek is through Gatun Lake, where it eventually meets with the Pacific and Atlantic Oceans on either side of the canal. On either side of the canal, two lock systems are situated. Each lock system descends from Gatun Lake to the Pacific and Atlantic oceans and vice versa. Similar to the way an elevator descends floors, each of the lock complexes on either side of the canal descend each of the three chambers. Once a vessel is in a chamber of one of the lock systems, the gates leading to the next chamber open, allowing the water levels to even out. Once the gates close,

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water either fills or leaves the chambers to allow the vessel to rise or fall into the level of the next chamber. Then, the gate opens and the same process is repeated until the vessel reaches either the Pacific or Atlantic ocean. This process including the 80 km voyage through Gatun lake takes an average of eight to ten hours per vessel transiting through the canal. This system is what is at the heart of the Panama Canal, and what fuels its success.

Due to the fact that there is not a substantial amount written about climate change and how it affects trade, this paper seeks to bring together the literature on climate change impacts on international trade, and that same international trade's impact on climate change. How does climate change ultimately impact relationships and patterns within trade, and how can we potentially change trade maneuvers to reduce our own contribution to climate change?

2. Methods

This paper relies on the method of literature review as a basis for analysis. Simply due to the fact that there are no sources that mention the discussed cycle as a whole, the many sources needed to analyse the topic need to focus on each individual piece in the cycle. To find these sources, specific searches were required to find valuable and informative papers. Common terminology used in said searches include: climate change, climatic events, welfare, difference-in-difference, international trade, CO_2 emissions. Furthermore, examples of such searches are as follows, ("fossil fuels" OR "carbon emissions" OR "air pollution") AND ("climate change" OR "natural disasters"), ("Panama canal" OR "drought") AND ("Supply chain" OR "firm trade costs" OR "consumer trade costs"), ("climate change" OR "CO_2 emissions" OR "Global warming") AND ("drought"). After conducting these searches, these sources were kept depending on their relatedness and value to each of the four primary links in the cycle: trade's impacts on environmental impacts, climate change and the economy, climate change and environmental impacts on trade infrastructure (in the context the Panama Canal), and damage on infrastructure to the overall trade industry. If sources were too general or covered too broad of a topic instead of detailing the certain factors, they were deemed to be excluded and invaluable to the research. The same applied for papers that were much too specific on certain topics than providing insight on the general relationships. Thus, using sources that depict each individual part of the cycle, yet in the specific context of the Panama Canal as an example, proves to be more efficient when making generalisations of the cycle in its entirety.

Table 1: Results from Literature Review Search

Paper	Link	Method	Outcome (variable)	Country	Main Finding (effect)
Yunfeng, Y., & Yang Laike, Y.	International trade → climate change	DID/input output model	CO_2	China	Trade increases emissions of the origin country by 5%.
Ramanathan, V., & Feng, Y.	Pollution → climate change	Literature Review	Production of harmful ABC clouds.	China	Atmospheric brown clouds(ABCs) are a major impact of climate change, reading to surface dimming.
Dai, A.	Climate change → drought	Literary Analysis	Drought	Global	Dought and chances of drought increase as global aridity increases.
Dellink, R., et al.	Climate change → International trade	Qualitative analysis/ literature review	Hindered trade	Global	Climate change affects both the supply-side and energy consumption sides of trade.
Clarke, D., et al.	International trade → Climate Change (CO_2 emissions and global warming)	Quantitative analysis	CO_2	Global	The increase of infrastructure/trade result in an increase of CO_2 emissions
Oh, C., H., & Reuvenyz, R.	Climate Change → International trade	Literary analysis	International trade	Global	Growth of economic globalisation may decline as climatic disasters increase
Shapiro, J. S.	International trade → Climate Change (CO_2 emissions and global warming)	Data regression	Trade inhibitors	Global	Climate change's effect back onto trade.
Lashkaripour, A.	Price of goods → shipping cost	Literary analysis	Trade costs and value	Global	Whenever there is a 10% increase in the price of an item, the nipping cost increases by 9.5%.
Suwanprasert, W.	Reduction in transport → welfare loss	Theoretical models	Welfare losses	Global	Reduction in transport costs result in welfare losses.

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3. Analysis

There is an apparent connection between the trade industry and climate change that makes itself especially clear when observing CO_2 emissions, specifically, emitted by those maritime transport industries.

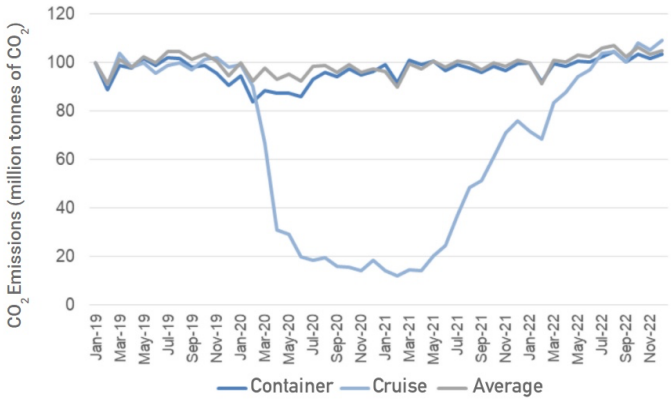

Figure 2. Monthly CO_2 Emissions From Container and Cruise Ships in Comparison To Average Air and Maritime Transport- 2019-2022 (OECD database).

As shown in Figure 2, of the majority of total CO_2 emissions from ships, container ships appear to be the leading cause of CO_2 emissions among air and maritime transport. This strongly supports how shipping and the maritime transport industry is a significantly large factor that aids the growing amount of CO_2 in our atmosphere (Clarke et al., 2023). Aligned with that fact, since the 1950s, climate change developments have been rapidly growing and changing at alarmingly fast rates. Climatic disasters, which are essentially natural disasters fuelled by climate change, are increasing as trends in climate change worsen. These disasters come in various ways, including heavy rainfall, heat waves, floods, droughts, and violent storms. Approximately 232 climatic disasters occurred in the 1950s, and 1,498 occurred in the 1980s, a remarkably stark difference. And from 2000-2008, 3,217 climatic disasters occurred. The growth of more advanced technologies that aid trade are allowing the industry to grow quickly, and with that growth comes the increase of climatic disasters and other such environmental issues. Over the next half century, it is estimated that world GDP is to increase by 2.5% yearly. This entails a linear relationship growing rapidly between climatic disasters and trade in the coming future.

Among environmental impacts caused by trade, is the creation of atmospheric brown clouds (ABCs), a jump in the amount of natural disasters, specifically climatic disasters, occurring more often yearly. As a result of CO_2 emissions through transport, ABCs are wide layers of air pollution that are primarily produced as a result of quick long-range transport causing air pollution between continents, appearing in the form of haze, smog, or acid rain (Ramanathan, V., & Feng, Y. ,2009). These harmful clouds not only pollute the air of cities and towns, impairing human vision and breath, but blocks view for maritime transport. That very quick long-range transport is what the majority of maritime transport industries are aspiring for in the upcoming years, as it benefits trade, potentially allowing for more air pollution similar to the ABCs. However, despite that desire, if that form of transport continuously grows, it threatens to increase air pollution, including the ABCs. Due to that, ABCs are becoming more abundant, and with the increase of ABCs comes the increase of several different climate issues. One of the most highlighted climate issues being surface dimming which is simply a decrease in the sunlight able to reach Earth's surface because of how the clouds physically hang over oceans, blocking sunlight. The general cycle or chain of events that appears shows that the greenhouse gas emissions, primarily CO_2 , ABCs and climatic disasters caused by production and gases released through transport cause environmental impacts and climatic disasters that result in hindrance to the trade industries reliant on those damaged systems. For example, Hurricane Katrina in 2005 left damages that cost over $180 billion. Such hurricanes, landslides, floods and powerful storms are the most violent, leaving nothing in their wake, and they threaten the majority of infrastructure that trade relies on.

Due to the fact that these particularly dangerous climatic disasters leave little to nothing to the places impacted, such damage ultimately brings threat to global economies. Because the world economy and countries' own economies rely so heavily on trade, these trade inhibiting climatic disasters prove to be very dangerous on a much wider level. Generally, trade is very reliant on a healthy environment, whether it's for agriculture and the production of goods, or communication systems. Due to the severe damage caused upon these storage, transportation, and communication infrastructure, a drop in production and overall reduced private and public spending is caused, slowing trade down significantly, potentially even bringing some industries to a halt. Whenever a country has an increase in climatic

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disasters, a decrease in bilateral trade has followed. These infrastructure-threatening climatic disasters and environmental impacts are a threat to trade, which as a result are a threat to the global economy and general welfare. However, they are derived from climate change, more specifically the emission of greenhouse gases, which is caused by trade reliant industries. So, the root of these obstacles is none other than the trade industry itself, and the only possible way to protect the world economy from climatic disasters may just be to cap greenhouse gas emissions and try to mitigate climate change as a whole.

As a whole, the Panama Canal is a perfect example of a trade infrastructure that has and is at risk of being hurt by climatic change caused by its booming business. Despite being the fifth-rainiest country in 2014, only a year later because of an overdue rainy season and drought caused by El Nino, Panama declared a national emergency, and water-saving measures began. Although this didn't severely damage or hurt the Panama canal, it almost certainly had an impact, as the amount of water required to function the locks of the canal during each transit is approximately 197,000 m^3. And 52 million gallons of water is released in the Atlantic and Pacific oceans from the average 35-45 ships that transit the Panama Canal daily. Furthermore, with Panama now having one of the quickest growing economies in the world since its acquisition of the canal, any threat to the canal brings a threat to the entire country's economy.

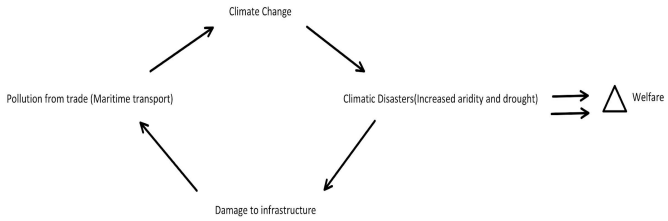

Figure 3. Framework of the Impacts of Climate Change on Trade in the Panama Canal.

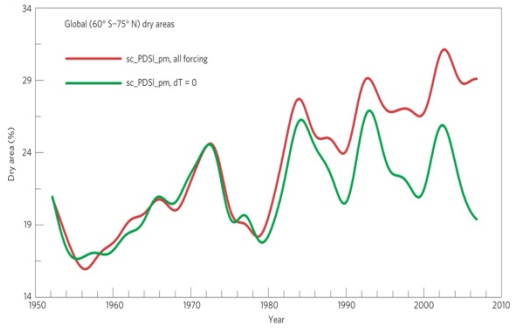

Figure 4. Percent Global Dry Areas (Dai, 2012).

Figure 4 shows the average percent dry area according to the Self-Calibrating Palmer Drought Severity Index, which essentially uses different environmental data to determine the dryness of a certain area, relative to one scenario with no droughts(shown in green), and one with all given climatic disasters including drought(shown in red). As Figure 4 shows, over the past 60 years, global aridity has been increasing rapidly. One of the largest concerns most clearly for the Panama Canal is their reliance on water, so most certainly any impact on dryness of a region would severely reflect on negative impacts. Furthermore, with the growth of aridity, comes a higher risk of drought. As years go by, and the environment becomes more dry due to the consequences of the trade industry's actions, the lakes and other such bodies of waters we rely on may not be able to be so dependable, just like those of the Panama Canal. A drought, stripping the lock system of the fuel the canal so heavily relies on, essentially shuts down the entire canal, no vessel being able to travel through it. Of course, the Gatun lake cannot be stripped of water as a whole, yet it would be disastrous if anything were to happen to the water that is stored next to the canal to transit vessels. On a general note, as climate change, specifically global warming, kicks into gear, a spike in droughts and less rain throughout the 21st century is becoming more of a reality as the speedy growth of aridity on our Earth's surface has already shown a trend of rapidly increasing. This presents a large threat to maritime transport industries such as the Panama canal. And due to the fact that a drought has already happened despite Panama being such a rainy country, the implications of increasing aridity lead to a realistic chance of the Panama canal finding itself in another drought. This example can be applied to the broader of the trade industry as a whole. If such a pivotal trade point that is the Panama Canal is being impacted by these factors, how does the rest of trade fare?

4. Discussion

The importing and exporting of goods across the world is at the heart of trade. How much is being traded and how many of those goods are sold are a few of the key factors that help determine the success of trade, where the more

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that is consumed only benefits trade, causing a demand in goods, in turn making an increase in trade generally a win-win situation for everyone involved. However, the startling rise in climatic events brings worry about whether this recent growth in trade can continue to flourish. As observed earlier, the environmental impacts caused by the trade industry is a significant contributor to climatic disasters that in turn physically deter those very industries and inhibit the growth as recently observed.

Due to these risks, it is imperative that something is done in order to protect general global economic welfare from being threatened by such disasters, and to further ensure no component of our observed cycle can effectively do their harm on the next, after all, although it is important to note trade's impact on the environment, it's important keep in mind the climatic disasters themselves and how we can better adapt to decrease their affects. Considering how far deep the issue has become, it appears as though in order to achieve this, all industries will have to aid in the reduction of greenhouse gas emissions, deforestation, and other harmful activities that directly result in climate change, also working to mitigate potential threats from the already existing excess of greenhouse gases. This risk has prompted attempts to reduce and remove as much air pollution and emissions as possible. Since many policies could mitigate these risks, it is imperative we act upon them. Primary actions include decarbonization, which partly involves working to reduce CO_2 emissions that are a result of the combustion of fossil fuels, by utilizing renewable energy instead (such as solar, wind, and hydropower sources), and to become efficient in overall business practice. It also incorporates physical attempts to remove the CO_2 already in the atmosphere through novel technologies. Overall, despite the harms of the industry, solutions for sustainable and efficient energy sourcing and practicing, as well as waste reduction and taking on systems of renewable energy are steps actively being taken to counter the threat of climate change.

5. Conclusion

In conclusion, there is a clear and evident connection between trade and climate change. That relationship is a domino effect, where the emissions from the trade industry's infrastructure contributes to, among other factors, the quicker growth of the prominence of climate change. Due to more rapid growth, we are left with more natural and climatic disasters. Those disasters in turn come back to physically harm the valuable infrastructure of the different trade companies that rely on them. A specific example can be seen through the Panama canal, where that connection brings threat to its rapid growth. The canal experienced a near-drought experience, and although it didn't result in a complete halt for the daily routines of the canal, it brought the threat of drought to reality, proving that it can happen. And as the danger of those risks increase, that threat becomes increasingly realistic. This cycle is key in our world today, because as climate change grows and develops, the threat to our global economy becomes more dangerous.

References

Calvo Gobbetti, L. E. (2013). Design of the filling and emptying system of the new Panama Canal locks. *Journal of Applied Water Engineering and Research*, *1*(1), 28–38. https://doi.org/10.1080/23249676.2013.827899

Carse, A. (2012). Nature as infrastructure: Making and managing the Panama Canal watershed. *Sage Journals*. https://journals.sagepub.com/doi/abs/10.1177/0306312712440166

Carse, A. (2017). An infrastructural event: Making sense of Panama's drought. *Water Alternatives*, *10*(3). https://www.water-alternatives.org/index.php/alldoc/articles/vol10/v10issue3/387-a10-3-13/file

Clarke, D., et al. (2023). CO_2 emissions from global shipping. *OECD Library*. https://www.oecd-ilibrary.org/content/paper/bc2f7599-en

Dai, A. (2012). Increasing drought under global warming in observations and models. *Nature Climate CHange*. https://www.nature.com/articles/nclimate1633#citeas

Dellink, R., et al. (2017). International trade consequences of climate change. *OECD Library*. https://www.oecd-ilibrary.org/content/paper/9f446180-en

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ISSN 2688-3651 [online]

Lashkaripour, A. (2015). *Worth its weight in gold: Product weight, international shipping, and patterns of trade.* Retrieved October 6, 2024, from https://ideas.repec.org/p/inu/caeprp/2015014.html

Miller, K., & Hyodo, T. (2021). Impact of the Panama Canal expansion on Latin American and Caribbean ports: difference in difference (DID) method. *Journal of Shipping and Trade*. https://link.springer.com/article/10.1186/s41072-021-00091-5

Oh, C. H., & Reuveny, R. (n.d.). Climatic natural disasters, political risk, and international trae. *Science Direct*. https://www.sciencedirect.com/science/article/abs/pii/S0959378009001009

Ohyama, M. (2016). *Macroeconomics, Trade, and Social Welfare*.

Pitacco, I., et al. (2021). On the design of the gate seals of the new Panama Canal locks. *Science Direct*. https://www.sciencedirect.com/science/article/abs/pii/S0141029621001474

Ramanathan, V., & Feng, Y. (2009). Air pollution, greenhouse gases and climate change: Global and regional perspectives. *Science Direct*, *43*(1). https://www.sciencedirect.com/science/article/abs/pii/S1352231008008583

Renee, C. (2022). What is decarbonization, and how do we make it happen? *State of the Planet*. Columbia University. Retrieved June 18, 2025, from https://news.climate.columbia.edu/2022/04/22/what-is-decarbonization-and-how-do-we-make-it-happen/

Rodrigue, J.-P., & Notteboom, T. (2015). *The legacy and future of the Panama Canal*. http://www.trb.org/Main/Blurbs/172350.aspx

Shapiro, J. S. (2016). Trade costs, CO_2 , and the environment. *American Economic Journal: Economic Policy*, *8*(4). https://www.aeaweb.org/articles?id=10.1257/pol.20150168

Suwanprasert, W. (2023). An Inconvenient Truth: Welfare Losses From Asymmetric Reductions in Transportation Costs. *International Economic Journal*, *37*(1), 71–81. https://doi.org/10.1080/10168737.2023.2169868

Yunfeng, Y., & Laike, Y. (n.d.). China's foreign trade and climate change: A case study of CO_2 emissions. *Science Direct*. https://www.sciencedirect.com/science/article/abs/pii/S0301421509007083

Zhu, S., et al.(2018). The environmental costs and economic implications of container shipping on the Northern Sea Route. *Maritime Policy & Management*, *45*(4), 456–477. https://doi.org/10.1080/03088839.2018.1443228