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Rcp – Based Coastal Paradox Modeling at Airports: Does Global Sea-Level Rise Affect Aviation?

Küresel Deniz Seviyesindeki Yükseliş Havacılığı Etkiler mi? Havalimanlarında Rcp - "Coastal Paradox " Tabanlı İnceleme

Pınar Demir[1], Didem Rodoplu Şahin[2]

ÖZ

İklim değişikliği her kıtayı, ülkeyi, şehri ve sektörü etkilemektedir. Bu etkilerin kapsamı, meydana geldikleri süre, küresel ısınmanın hızı ve yapılan önleme eylemleri tarafından belirlenmektedir. İklim değişikliğinden en çok etkilenen sektörlerden biri de havacılık sektörüdür. Havaalanlarının kapanması, havayollarının mevcut rotalarında değişikliğe gitmesi, artan işletme giderleri ve yeni yasal yükümlülüklerin belirlenmesi gibi zorunlu uygulamalara geçilmesi iklim değişikliği sonucunda beklenebilir.

İklim değişikliği kaynaklı meteoroloji olaylarının havacılık sektörüne etkilerinin şu andan itibaren olması öngörülüyor. Fırtınalar ve aşırı sıcaklıklar operasyonel gecikmelere, uçuş iptallerine ve altyapı kesintilerine neden olabilir. Uzun vadede sıcaklık değişimi veya küresel deniz seviyesinin yükselmesi sonucunda , yolcu talebindeki değişiklikler, yeni havacılık merkezlerinin oluşması, mevcut cazibe noktalarının kaybolması ve altyapı hasarları gibi ekonomik faaliyetlerde kademeli ancak daha kalıcı etkiler meydana gelebilir.

Bu çalışmada iklim değişikliği kısıtlamalarının başta havaalanları olmak üzere havacılık sektörü üzerindeki etkileri analiz edilmektedir. Yükselen su seviyelerinin havaalanları üzerindeki etkileri ve geleceğe yönelik öngörülen senaryoları incelenmiştir. Örnek modelleme yoluyla, belirlenen havaalanları istatiksel veriler kullanılarak oluşturulan muhtemel gelecek senaryoları araştırılmıştır. Bu çalışma, gelecekteki küresel deniz seviyesi artışlarını modellemek için "Coastline Paradox" tabanlı aracı kullanır. Çalışmanın bulguları 2050-2200 yılları arasındaki sürece dayanmaktadır. Çalışmada, iklim değişikliğinin havacılık üzerindeki etkileri incelenmiş ve küresel deniz seviyesi yükselmesiyle kullanım dışı kalacak havaalanları tahmin edilmiştir. Çalışmanın amaçlarından biri de havacılık otoritelerini ve kurumlarını bu yıkıcı sonuçlara karşı bilinçlendirmek, gerekli hazırlık ve önlemlere katkıda bulunmaktır. Çalışma, havacılık merkezleri olarak kabul edilen Avrupa ve Amerika'daki havaalanlarına odaklanmıştır.

ABSTRACT

Climate change affects every continent, country, city, and sector. The extent of these effects is governed by the period over which they occur, the rate of global warming, and the mitigation actions employed. One of the sectors most affected by climate change is aviation. Climate change may result in mandatory rules such as airport closures, airline route changes, increased operational expenses, and new legal duties, among several other things.

Weather events caused by climate change are projected to impact the aviation industry immediately. Storms and excessive temperatures can cause delays, cancellations, and infrastructure disruptions. In the long term, gradual but more permanent effects can occur in temperature change or global sea-level rise, changes in passenger demand, the new aviation hubs, the loss of existing attraction points, and economic repercussions such as infrastructure damage or loss.

The effects of climate change restrictions on the aviation sector, particularly airports, are analyzed in this paper. The consequences of rising water levels on airports and future scenarios are examined and projected. Through sample modeling, the future scenarios that a few airports are likely to encounter have been investigated using statistical data. This study uses the Coastline Paradox-based tool to model future global sea level rises. The study's findings are based on projections for 2050-2200. The study, the effects of climate change on

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aviation have been examined, and airports that will be out of use due to global sea-level rise have been estimated. One of the aims of the study is to raise awareness of aviation authorities and corporations about these devastating consequences and to contribute to their necessary preparations and precautions. The study looked at airports in Europe and America recognized as aviation centers. The applied working techniques and analyses are described in depth.

Keywords: Climate change, Global warming, Global Sea level, Airports, Aviation Industry

INTRODUCTION:

The causes of global warming are seriously issue for aviation. This study examines and analyzes the effects of global warming on the aviation industry regarding global sea level rises.

The key factors of climate change projected to affect the aviation industry are global sea level, temperature, changes in wind storm patterns, and precipitation. Temperature fluctuations have a direct impact on aircraft performance. Precipitation intensities are constantly shifting, causing delays and cancellations. The capacity of airports may be reduced when the world's sea level rises, causing network disruption. Airports that have fallen below global sea level over time are one of the reasons that are likely to impact the aviation sector due to climate change. Turbulence intensity and intensity can be increased by changing the wind type. This circumstance results in a shift in travel schedules, resulting in flight delays and an in-flight reduction in comfort. There are also expected macro consequences in addition to these operational micro effects.

Global warming, which has resulted in numerous changes, will continue to have socioeconomic consequences. The aviation industry must take precautions and make risks as predictable as possible during this procedure.

1. THE EFFECTS OF CHANGING CLIMATE ON WIND,TEMPERATURE LEVEL,DEMOGRAPHICS AND GLOBAL SEA LEVELS

Even though the Covid-19 pandemic has dominated the worldwide agenda in recent years, the threat posed by global warming to our planet has not gone—climate change, which originates with increased atmospheric warmth, increases as human-induced carbon dioxide emissions rise. As a result, the temperature rises. The rise in extreme weather events and the melting of the polar ice caps are two of the most significant impacts.

Although future effects of human-caused climate change are projected, environmental and community impacts are already increasingly being recognized. Between 1901 and 2020, global temperatures increased by around 1.1°C, but the effects of climate change are much more severe. Natural disasters such as rising international sea levels, droughts, floods, and storms are caused by climate change. Furthermore, indirect effects of climate change include pollution of spring waters, decreased energy efficiency, transportation issues, ecosystem degradation, including wildlife, reduction in agricultural regions, and a bad influence on human health (Special Report, 2022,chapter-3,sr15).

1.1. Variable Winds and Intensifying Storm Formation

Hurricanes and storms are examples of the effects of human-induced global warming.

Storm: The wind, a horizontal movement of air, exerts a force on the surface it blows across. The amount of energy it exerts is determined by the wind's strength. Using the Beaufort scale, winds are

classified as calm, light air, light breeze, gentle breeze, moderate breeze, fresh breeze, strong breeze, moderate gale, fresh gale, strong gale, whole gale, storm, and hurricane.

Hurricane: According to the Beaufort scale, it is air with a magnitude of 8 Beaufort, which causes the sea to turn white with foam and visibility to be reduced in winds exceeding 34 nautical miles *(Terry, 2007:50-78).*

Major hurricanes can cost over a hundred billion dollars in damage to cities. As a result, it's one of the most costly natural disasters. These negative consequences are projected to worsen as the climate crisis continues, and studies show that they are becoming more substantial and more harmful by the day (*Berardelli, Yale,2019)*

When viewed through the lens of the aviation sector;

Weather disruption is one of the most common causes of air traffic disturbance. As a result, increased winds and storms severely impact the aviation industry, particularly airports. Airlines incur additional costs due to delayed and canceled flights; flight diverts to other airports, motels, transfers, meals, and compensations that must be provided to passengers. After large hurricanes, substantial financial losses occur due to damage to aviation fixtures, which are pretty high-cost items. Airports may need to be rebuilt or upgraded due to wind-related incidents. (Koetse, M. J., & Rietveld, P. (2009). *Transportation Research Part D: Transport and Environment*, *14*(3), 205-221).

1.2. Constantly Changing Temperature Scale

A plane's performance, including takeoff distance, rate of climb, and engine power, is greatly affected by the density of the air(density altitude). Generally, both turbine and internal combustion/reciprocating piston engines run more efficiently in cold air because colder air allows the engine to use a greater mass of air/fuel mixture in the same intake volume and more power. (Sadraey, M. H. (2017). *Aircraft performance: an engineering approach*. CRC Press).

The standard temperature in aviation is measured at the mean sea level (msl) pressure of 29.92 inches of mercury (Hg) and is 15° C or 59° F. The standard temperature decreases 2 °C or 3.5 °F for every 1,000 feet gained, and this is reasonably accurate up to 36,000 feet msl. From 36,000 feet to 80,000 feet msl, the temperature zone is considered constant around –55 °C or –65 °F.

In addition to degraded engine performance, aerofoil performance is also affected by high ambient temperatures. As discussed previously, an increase in temperature results is an increase in density altitude. The higher the density altitude, the fewer molecules there are per volume of air. This results in a decrease in the amount of lift that the wings will generate.

(Sadraey, M. H. (2017). *Aircraft performance: an engineering approach*. CRC Press).

Increased ground-level air temperatures result in a decrease in air density. In aviation, these variable temperature levels are closely linked to aircraft performance. The low air density has a negative impact on the aircraft's lifting force. At constant pressure, the air density falls as the temperature rises. At a given airspeed, an airplane wing generates less lift in this situation. Due to these limits, airplane performance suffers, and full capacity passenger-cargo fuel loading is not possible. As a result, significant modifications in flying ranges have occurred (ICAO, 2016,chapter7).

When viewed from the perspective of the aviation industry;

Flight cancellations occur when the cold weather in northern climate zones exceeds the aircraft's capabilities. In such weathers, significant rises occur in the cost of heating terminals and other airport facilities. Meanwhile, the impact of global warming on meridian temperature gradients significantly changes the spatial-temporal variability of the jet stream. It is becoming increasingly recognized that it increases the turbulence frequency worldwide, especially in the mid-latitudes (Storer, *Geophysical Research Letters,*2017,9976-9984).

This means that winds in the upper atmosphere and large-scale flow patterns can significantly impact long-haul flight efficiency and safety. It has a substantial impact on global aviation security (Jenkinson, *Civil jet aircraft design. Vol. 338.* 1999).

The jet stream roughly occurs between 33,000 and 39,000 feet in the Northern Atmosphere's mid-latitude zones. They are typically cruising altitudes, and the most vulnerable sections of the flight, during which passengers and flight crew members often unbuckle their seatbelts. Many major turbulences have resulted in adverse outcomes (Sharman, 2006, *An integrated approach to mid- and upper-level turbulence forecasting." Weather and forecasting 21.3:268-287*).

As a result, the relationship between the jet stream and turbulence in the upper atmosphere is critical for flight. The fluctuation of the jet stream is extremely sensitive to changes in air temperature. Palmén (Palmén, 1948). The position and intensity of the jet stream are also influenced by large-scale teleconnection link patterns like the North Atlantic Oscillation (NAO). As a result, it is necessary to alter the previously planned flight routes (Lv,2021, *." Earth and Space Science 8.2*).

1.3. Increases in Precipitation and Affected Demographics

Climate change has the potential to increase precipitation intensity and frequency. The warming of the oceans leads to more evaporated water, therefore, more humidity. This humidity rate turns into heavy rains and snowstorms due to the movement of dense air (Wuebbles, 2017, *US Global Change Research Program: Washington*).

The agriculture sector, humanity's natural food source, is harmed by heavy rainfall. Irregular precipitation causes flooding, reducing crop yield and leading to famine. In the future, the possibility of a loss of agricultural lands by damage is likely to cause forced migration, starvation, diseases due to lack of basic food. All of these shifts have an impact on the demographic structure (Myers, 2002, *Biological Sciences, 357 (1420):609–613*).

When viewed from the perspective of the aviation industry, unpredictably heavy rainfall transforms into floods, causing damage to runways and infrastructure. Floods cause flight delays and cancellations by reducing capacity. This natural occurrence disrupts the entire flight route, resulting in revenue loss, higher operating costs, and passenger dissatisfaction. These migrations and demographic shifts are likely to change the demands of airports.

1.4. Global Sea-Level Rise

Coastal locations are home to the majority of the world's population. Airports are typically built in low-lying coastal locations in cities near seas and oceans. On the other hand, some airports are constructed on artificial lands such as filled soils and dried marshes (Griggs, 2020, *Journal of Coastal Research 36.,1079-1092*).

This type of placement is done for a variety of reasons:

- Difficulty in finding flat pieces of land of a specific size in or near large towns

- Low cost and accessibility of coastal areas

- Absence of nearby tall buildings or obstacles that could endanger aviation

- Absence of a community that will be affected by noise pollution during take-offs and landings,

When these urbanization conditions are viewed from the point of the aviation sector, the worldwide sea-level rise threatens to flood airports.

However, when many of the world's largest coastal airports were constructed, the global sea-level rise was not considered. According to current research, global sea-level rise will pose decades-long unprecedented problems to airport operations.

Extremely high tides, storm surges, cyclones, typhoons, rare tsunamis, and rising global sea levels pose severe threats to these major coastal airports. In 2100, if the world average temperature increases by 2 degrees, 100 airports will be flooded, and 364 airports will be at risk of flooding *(Yesudian 2021, Global analysis of sea level rise risk to airports." Climate Risk Management 31:100266).* This study examines and analyzes the hazards posed by rising global sea levels to the aviation industry, mainly due to changing climate effects. Global sea-level rise has a significant impact range that generally affects aviation investments, not short-term periodic operations or expenses.

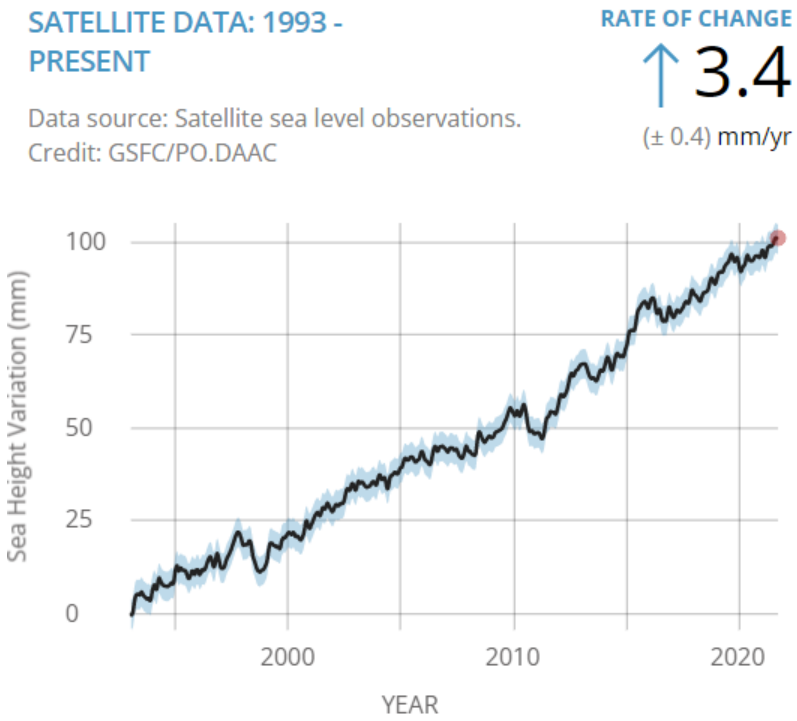
2. GLOBAL SEA LEVEL

The reasons and consequences of changes in global sea level and how these changes are measured should all be examined.

2.1. Global Sea Level Changes

Global sea level is defined as the average height of the entire ocean surface. There are two main reasons for this level's rise through time, related to global warming: The addition of the melting ice masses in the land to the water in the glaciers; the expanding seawater due to the rising seawater temperature averages *(Beckley, 2017).The Physical Oceanography Distributed Active Archive Center (PO.DAAC)*

Global Mean Sea Level 1993-Present-Table.1.

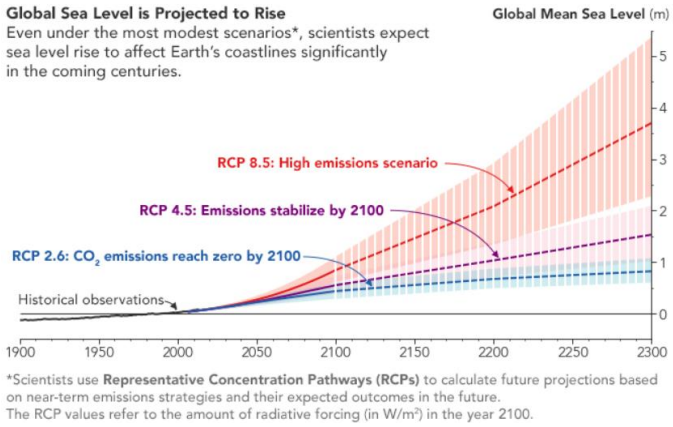


The global sea-level change detected by satellite altimeters from January 1992 to today is shown in this table. The measurements are represented by the black line, while the blue areas represent the level of uncertainty in these measurements. There may be deviations of up to 4 months in the measurement values in the table. This table shows that an annual sea-level rise of 3.4 mm has been observed since 1998 (Chuech, 2011, *Surveys in geophysics 32.4:585-602.*).

2.2. Global Sea-Level Significance

Because of the consequences, it is critical to comprehend the global and regional sea-level variations during the 20th century. The impact of the world's climate system on natural and anthropogenic changes affects hundreds of millions of people who make a living in the coastal regions of the world. Since 1993, satellite altimeters have shown that the global sea level has increased at a pace of 3.1-+0.3 millimeters per year. Since 2005, these results have been obtained by observing the intensity changes at 2000 mt. from the ocean's surface via gravimetric satellites (*Cazenave, 2018, ." Earth System Science Data 10.3:1551-1590)*

The global sea level is steadily rising. Impacts vary depending on several factors, primarily geography. Coastlines are at higher risk than other areas. Global sea-level rise is expected to continue at a rate of 1 to 4 feet per year by 2100, with different effects on transportation depending on location and geography. As the sea level rises, storm surges will become more powerful. It is anticipated to spread into the interior parts, causing significant damage. In some coastal places, the global sea level is expected to increase even more. Even without the storms caused by regional land collapse, it is estimated that this circumstance will inflict significant damage to transportation infrastructure. Based on these expectations, airports on all coastlines will need to be restructured *(Titus, J. G., Park, R. A., Leatherman, S. P., Weggel, J. R., Greene, M. S., Mausel, P. W., ... & Yohe, G. (1991). " Coastal Management 19.2:171-204.).*



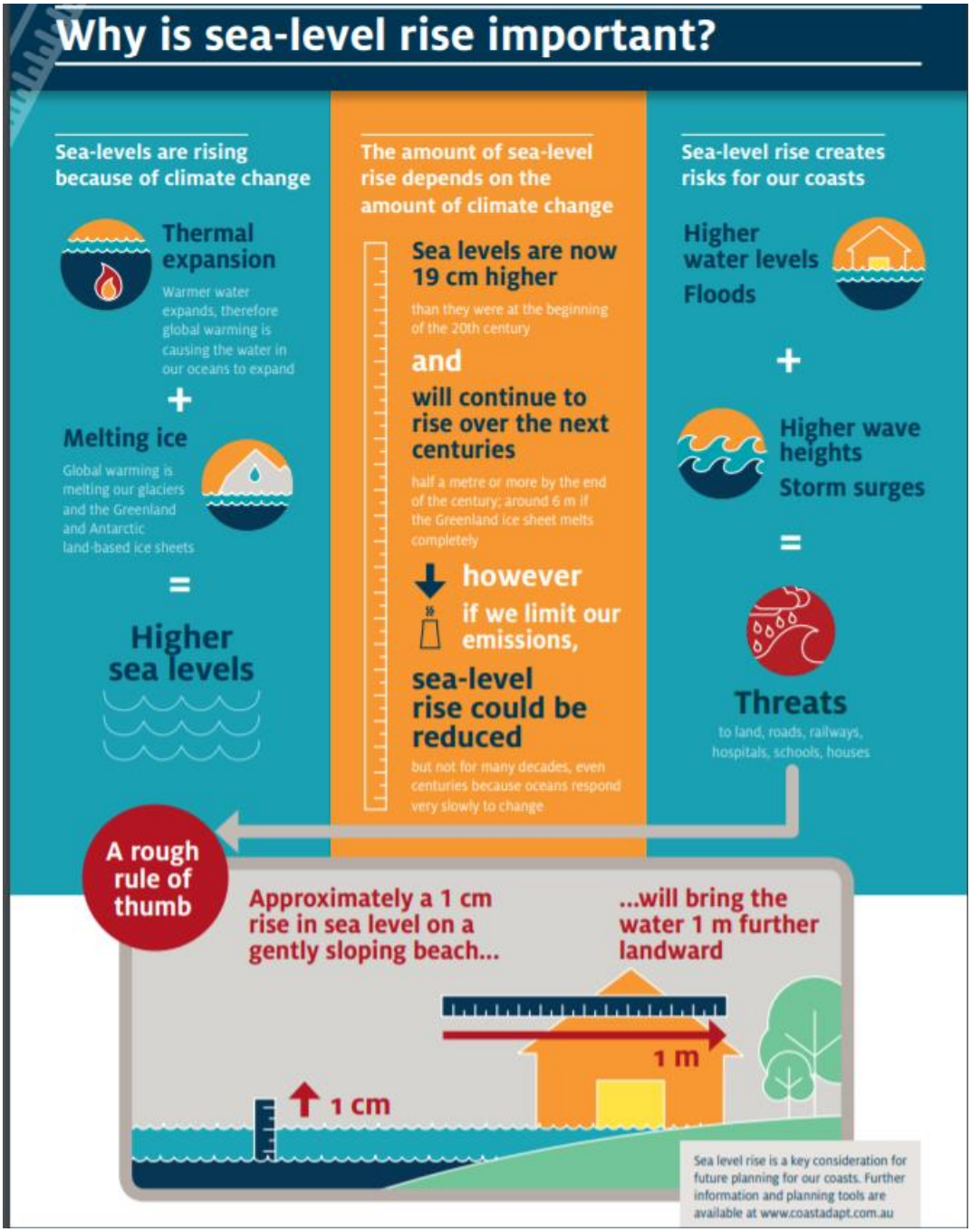
[https://earthobservatory.nasa.gov/images/148494/anticipating-future-sea-levels]

Graphic.1. Global Sea Level is Projected to Rise 1900- 2300

Measurements are made by comparing data from various sensors at various sea levels with physical characteristics. The pressure, density, and depth changes of seawater are used to make thermodynamic measurements. Furthermore, pressure and atmospheric pressures formed in tide gauges on the ocean floors are used. The water level can also be estimated with radar, thanks to the physical waves that radar waves produce in the ambient air. For these measurements, there are two types of radar sensors. These are frequency module continuous-wave radars (FMCW) and motion sensor radars (Wang, G., Munoz-Ferreras, J. M., Gu, C., Li, C., & Gomez-Garcia, R. (2014). *IEEE transactions on microwave theory and techniques*, *62*(6), 1387-1399).

2.3. The Significance of Global Sea Level Rising

There are many risks associated with rising global seawater levels. Some of these risks include increased floods, flash floods, and storms.



Infographics.1.

https://www.coastadapt.com.au/infographics

Erosion and tides are common in coastal areas. When these tidal zones change, the ecosystem deterioration will have adverse environmental, social, and economic effects. The marine ecosystem, which will be developed in the medium-long period by the mingling of salt water and fresh water, is another example of ecological degradation. Stormwater drainage, sewerage systems, and urban infrastructures will encounter problems when average sea levels rise. Changes in water regimes will cause the degradation of lakes, lagoons, and estuaries. In the face of increasing threats, existing seawalls and other conservation engineering efforts remain insufficient (Reimann, L., Vafeidis, A. T., Brown, S., Hinkel, J., & Tol, R. S. (2018). *Nature communications 9.1:1-11*).

Even if emissions are reduced, global sea level rises will be too late to benefit from these gains. As a result, preventing future sectoral and social losses is difficult. Global warming should be avoided, and other engineering-based solutions should be applied. City plans, industrial structures, infrastructure systems should be re-planned according to these risks.

3. Impact of Global Sea Level Rising on the Aviation Industry

Thermostatic expansion of ocean waters and melting of land ice are the two main components of global mean sea-level rise. Due to the long response times of the ice sheets and the deep ocean temperature, these processes are expected to persist for centuries even after the surface air temperature stabilizes *(Nicholls,2018).* The amount of water stored in dams, for example, is one of the indirect factors impacting the global average sea level (*Frederikse, 2020).* The aviation industry is one of the main sectors that will suffer from global sea-level rise. One of the critical reasons for this hazard is the significant number of airports located along coasts. Because cities currently recognized as aviation centers will be flooded, aviation centers in these cities will be forced to cease operations. Due to the significant technological elements that the aviation sector incorporates in its investment expenses, this scenario is costly for the industry. In addition, the demand for trained employees necessitates extensive training, experience, and financial support. The reconstruction and re-employment of aviation centers that will be out of service will require large-scale financial support. According to these projections, the globalized aviation sector will have a domino effect, resulting in even more severe negative consequences.

Three scenarios compatible were evaluated to investigate the projection range for global sea-level rise:

1) Stabilization of 1.5°C warming in the global average temperature this century: 52 cm (median), 87 cm (95%) by 2100;

2) Global average temperature stabilization at 2.0 °C warming this century: 63 cm (median), 112 cm (95 percent) by 2100; and

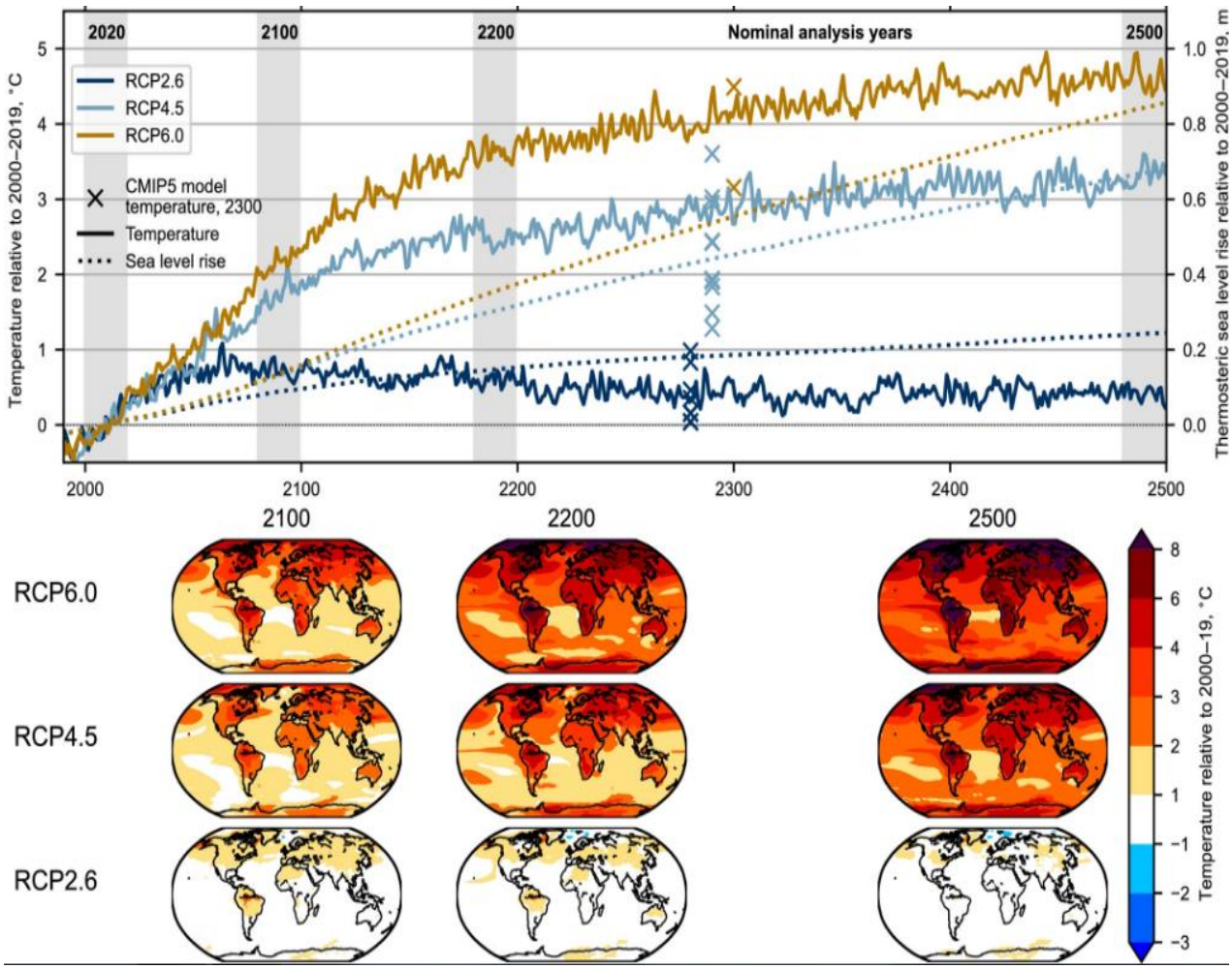
3) Representative Concentration Path 8.5 (RCP8.5) provides high baseline emission scenarios, including contributions from Greenland and Antarctic ice melt, for the 21st century: 86 cm (median), 1.8 m (95 percent) to 2100.

According to the 2018 study of Jevrejeva et al., various scenarios exist according to the stabilization of the global average temperature.

RCP Method: Observes a wide range of possibilities for future anthropogenic emissions. The carbon cycle is studied by focusing on greenhouse gas concentrations rather than greenhouse gas inputs. It is divided into several categories.

The carbon cycle is studied by focusing on greenhouse gas concentrations rather than greenhouse gas inputs. It is divided into several categories. Socioeconomic assumptions drive its four primary segments (*Jevrejeva, 2018, Environmental Research Letters 13.7:074014)*

RCP is an IPCC-approved method for measuring greenhouse gas concentrations. As part of climate modeling that began in 2014, different scenarios are generated based on the volume of greenhouse gases emitted in the coming years.(Special Report Global Warming (2022). - *special report: global warming of 1.5 ºc.IPCC).*



Graphic.2.

https://www.onlinelibrary.wiley.com/doi/10.1111/gcb.15871-Figure.1.

Some studies forecast quicker ice melting; for example, Bamber et al. (2019) predict a global sea-level rise of more than 3 meters by 2100. Local subsidence and isostatic adjustment can affect relative sea-level height at specific sites, while local bathymetry and coastal landform impact local water levels during storms. These local conditions are not simulated here, so airport risk for a global sea-level rise between 0 and 5 m has also been calculated to understand the sensitivity of the effects to global sea-level rise.

3.1 GLOBAL SEA RISE SCENARIOS

The following are the projected impacts of global sea-level rise, according to the aviation body ICAO's scenarios:

- Rising global sea level can increase flooding, causing more coastal area erosion,

-There is a need to strengthen or rebuild the airport infrastructure,

-If airport use is restricted or parts of regions are flooded, local tourism sectors may be directly impacted, posing a difficulty for small island developing countries,

- There is a possibility that low coastal aviation infrastructures such as aviation navigation equipment and airport assets, land transportation will be submerged,

- Due to flooded areas, access to the airport is restricted,

-Increased airport infrastructure problems may arise due to storm surges, reduced drainage system performance, and increasing infrastructure difficulties at coastal airports.

- Storm surges generate non-consistent rises in global sea level (ICAO Climate Change, 2020)

3.2 Compliance and Durability Measures

Many environmental agencies, particularly aviation authorities, provide recommendations and safety guidelines.

Specific vulnerabilities and timelines must be identified, adaption measures implemented, and operational resilience strengthened in locations where impacts from global sea level rise are currently being experienced or are predicted in the near to medium term.

Maritime defense systems and other preventive measures for vulnerable locations are examples of potential adaptation and resilience strategies. This includes upgrading or relocating critical infrastructure, building or re-enforcing sea defenses, preserving or introducing natural barriers, allowing for safe levels of flooding, and developing new secondary airports that are not affected by global sea-level rise.

Global sea-level rise projections should be considered when building new airports in coastal areas. Forecasts of global sea-level rise and vulnerabilities are assessed at the local level.

These recommendations, which are advisory in nature, are critical for future projections for airport establishment sites, selection, and airline strategic plans (ICAO *Climate Adaptation Synthesis Analysis, 2018)*.

(https://www.airlines.iata.org/analysis/2050-net-zero-carbon-emissions)

4. Effects of Global Sea Level Rising on Aviation-Coastal Paradox review created with RCP-Based Modeling

The figures released by the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate (2019) are used to predict how global sea levels would rise in the future.

The figures in the paper are based on one of the most recent scientific ideas about global sea-level rise as a result of global warming.

The RCP8.5 scenario, which assumes very high and rising CO^2 and other greenhouse gas emissions by humans, is used to calculate global sea-level rise. RCPs, or Representative Concentration Paths, are several climate model scenarios developed by the IPCC. Various RCPs aim to provide reasonable estimates of how emissions and greenhouse gas concentrations in the atmosphere may change over time.

https://www.ipcc.ch/srocc/download-report/

Coastline Paradox is an interactive internet art experiment, as is expressed by Finnish artists Pekka Niittyvirta and Timo Aho. The project simulates climate-related migration and visualizes potential global sea-level rise. This modeling is based on RCP 8.5 uncontrolled emissions. Data from IPCC

(Intergovernmental Panel on Climate Change) and Climatecentral were used. The artists visualized the already available technical information, metrics via Google Street.

A custom-built map interface and Google street views are used to reflect the effects of the climate issue on the user. Global sea-level rise is represented by the shadow areas reflected on the globe and the horizontal line marked in the street view. This interactive parameter can be modified over time to see the implications of an artificial environmental calamity.

(*https://www.artsexperiments.withgoogle.com/coastline-paradox/)*

The results of this human-induced environmental disaster can be viewed at various time intervals.

The survey included airports from Europe and America that were chosen at random. These airports are desirable places to work since they are aviation hubs with the densest flight network in the world's aviation traffic and areas and large-scale economic operations. At the same time, these airports are popular for both leisure and business travelers. Many industries, particularly the aviation industry, will be adversely affected due to the economic losses and forced migrations that will occur here.

Existing activities will be shifted to other centers or newly established businesses as current centers are flooded shortly. The date range for global sea rising –30 years later – is selected as the medium-term range in the study. The years 2050-2200 are chosen as the date. Those airports predicted to be affected shortly and those expected to face the same adverse effects step by step over time were prioritized.

Amsterdam Airport Schiphol Coastal Paradox Modeling-2050

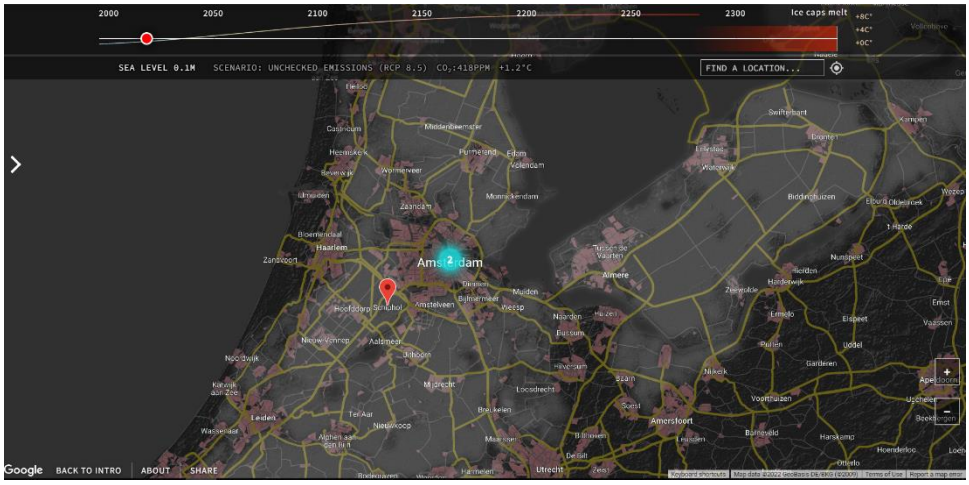
Since 2000, the global sea level has risen by 0.3 meters. Famines have begun as summer temperatures have reached lethal levels. By the year 2150, it is estimated that 0.1 million people will have to relocate from their residences within a 5-kilometer radius of Amsterdam's city center. The CO2 level is 567 parts per million. The canals, which play an essential role in Amsterdam's geographical structure, are expected to speed up the process of city center formation.

Annually, 496,826 scheduled charter flights, including general aviation; 71,706,999 passengers, including transit passengers; and 1,570,261 tons of cargo were transported at Amsterdam Airport, according to figures from 2019. It is estimated that there will be a revenue loss of roughly 1.615 million Euros together with other regional airports if the airport with this capacity is not utilized.

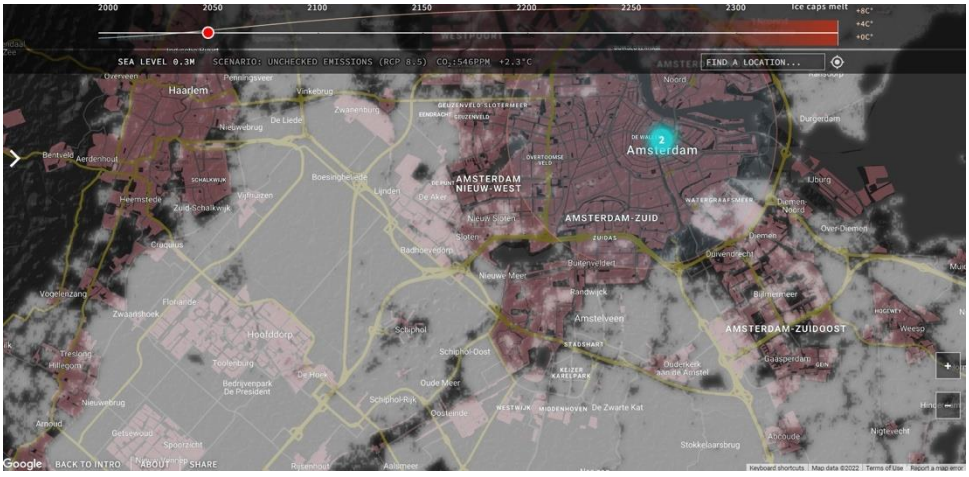
https://www.annualreportschiphol.com/trafficreview2019/summary

The Binnenstad district, which includes the well-known Dam Square and the historical center, will be entirely flooded. Today, there are many hotels, historic places, and businesses in this tourist area.

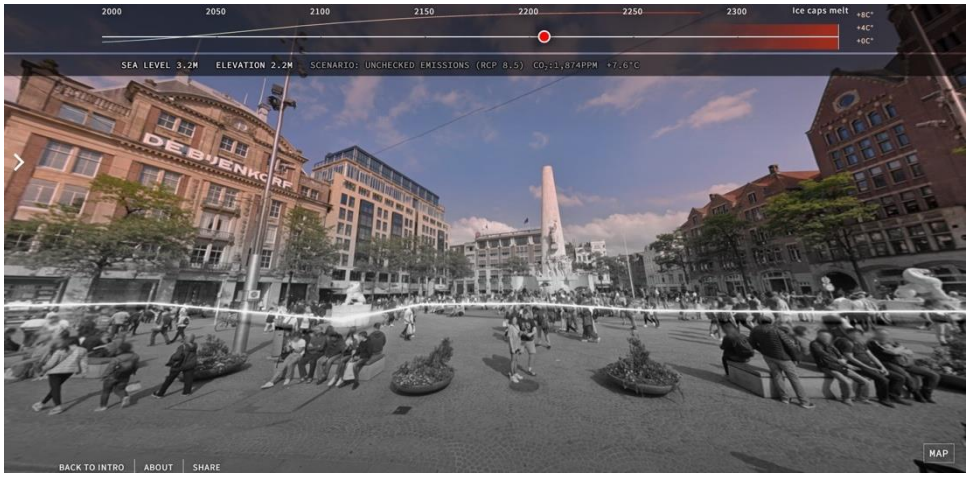
According to Coastline Paradox application data, Schipol Airport, one of Europe's busiest aviation bases, will be fully flooded by 2050. The area painted on the city map indicates the area that will be completely submerged with a 0.3 m rise in water levels.



Coastline Paradox.1. Schipol Airport-Present



Coastline Paradox.2. Amsterdam City Center-2050



Coastline Paradox.3. Amsterdam Dam Square-2050

https://artsexperiments.withgoogle.com/coastline-paradox/?mode=map&lat=52.33907801934555&lng=4.806409832976266&zoom=12&alat=52.37299&alng=4.8932&arad=5000

Economic losses in the region will be added to the aviation-related income losses when the area becomes useless. The airport will lose its current passenger and freight traffic density due to the

forced migrations that will occur in the first place. It will be worthless after that. The rising water level is likely to harm about 50 kilometers of land away from the sea coast.

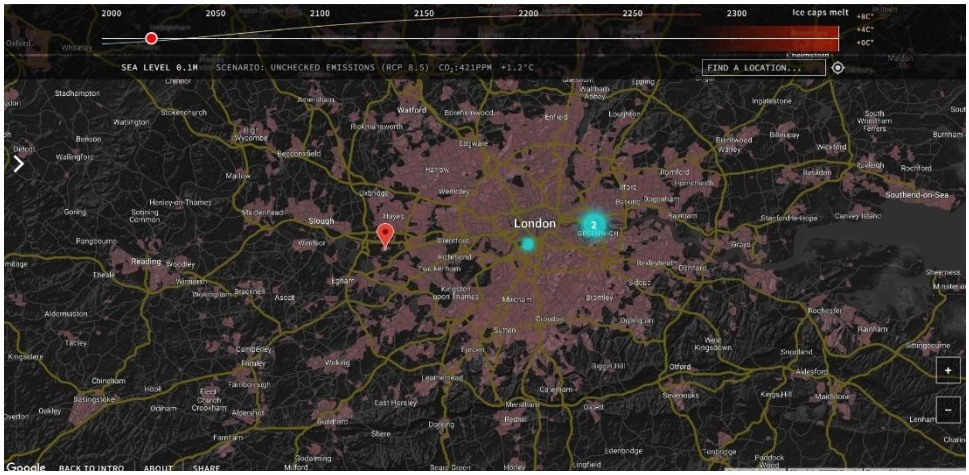
London Coastal Paradox Modeling-2200

Since 2000, the average sea level in London has risen by 2.9 meters. Human-induced temperature incompatibilities have occurred. The global ecosystem has essentially disappeared. Around 0.2 million people were forced to relocate within a 5-kilometer radius in the area illustrated. The CO^2 level is 1,845 ppm. (CO^2 concentration)

Heathrow Airport in London is one of the world's busiest international airports. The airport, which also serves as a hub for British Airways, is the largest of London's six airports. An average of 1,300 flights are made per day, according to 2018 data. With a freight volume of 1.70 million metric tons and a revenue stream of 2.97 million pounds, it serves more than 80 million passengers yearly.

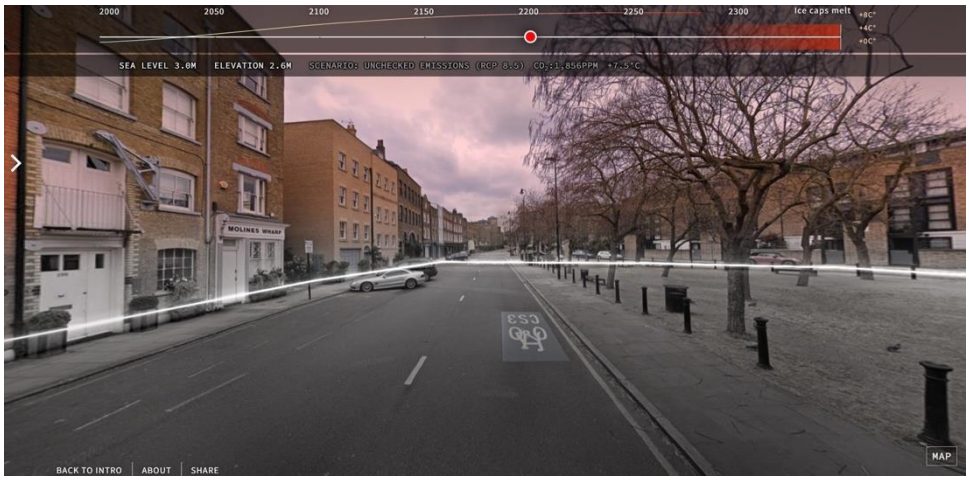
https://www.heathrow.com/company/about-heathrow/performance/airport-operations/traffic-statistics

Although flooding occurred in the city center in 2200, major flooding is not expected at Heathrow airport. However, the airport will suffer a severe loss of income due to the forced migrations in the city and the raids due to the global sea-level rise in the neighboring countries. Therefore, with the formation of the predicted scenario, one of the most important aviation centers in Europe will be flooded.



Coastline Paradox.4. London Heathrow Airport-Present

Coastline Paradox.5. London Heathrow Airport-2200

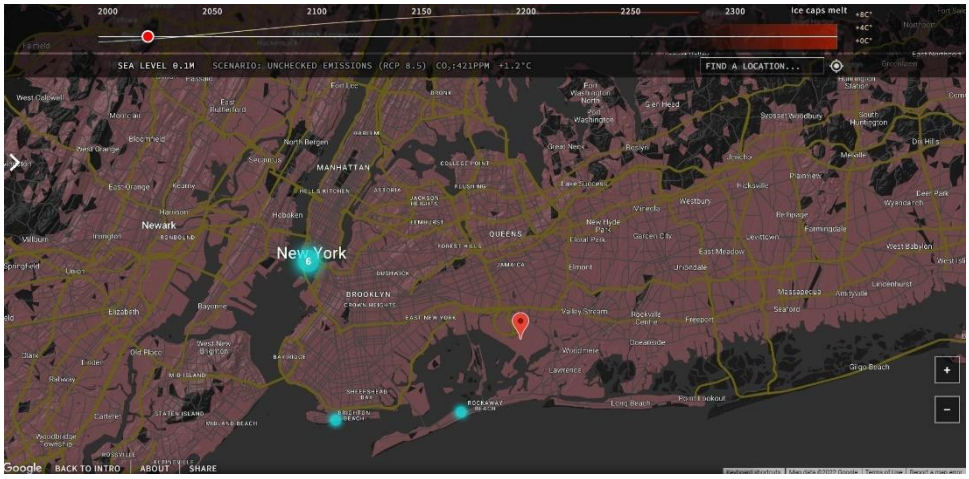


Coastline Paradox.6. London City Center (Limehouse)-2200

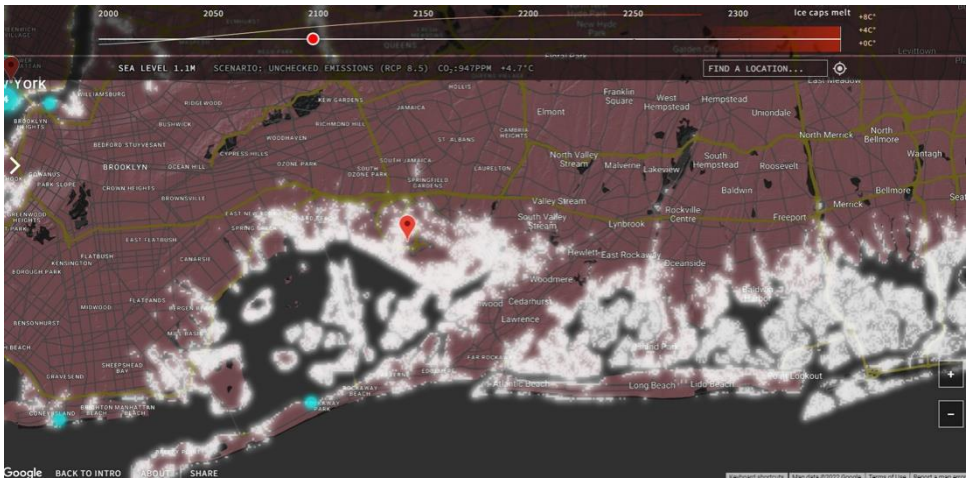
Because of its proximity to financial circles, the Limehouse region has a high standard of living. Because of its proximity to the canal roads, the area held a significant position in the past. In addition to the aviation sector, the region's floods will negatively impact the banking sector.

New York Coastal Paradox Modeling-2100

Since 2000, the global sea level has risen by around 1.1 meters. Ecosystems worldwide have been destroyed due to global warming's detrimental effects. A total of 47 thousand individuals were forced to relocate from a 5-kilometer radius. The CO^2 level is 967 ppm.



Coastline Paradox.7. John F.Kennedy International Airport-Present



Coastline Paradox.8. John F. Kennedy International Airport-2100

Coastline Paradox.9. New York city center-2100

New York is one of the most populous cities in the United States and globally, with a diverse range of enterprises in the arts, fashion, technology, education, entertainment, and finance. As a result, rising water levels in this area will result in significant financial losses. The city's structure will change due to population changes brought on by migration. Because of this attribute, the city, a natural harbor, has a high-risk rate. The water level is predicted to rise around 5 kilometers from the sea coast to the mainland.

According to 2019 data, JFK (John F.Kennedy International Airport) is one of the busiest airports in the world, serving around 62,551,072 passengers per year, 456,060 flights per year, and 1,336,520

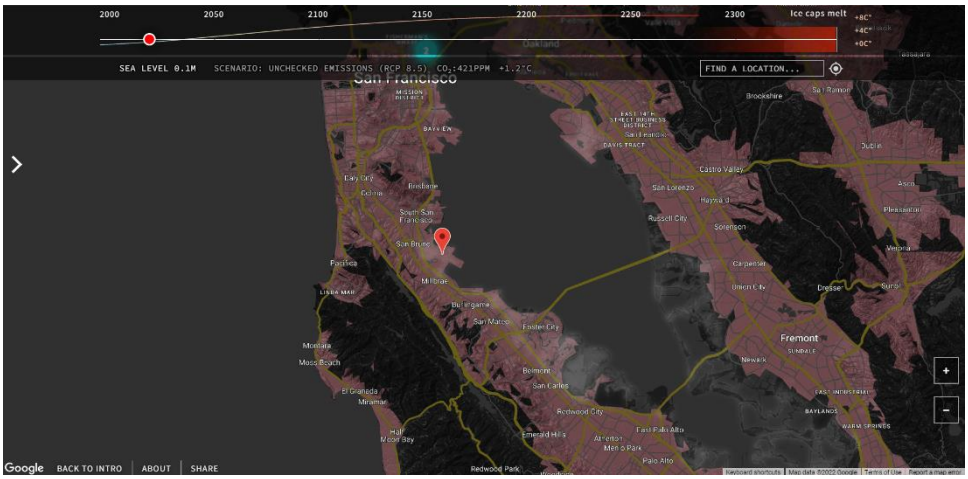
tons of cargo per year. According to 2019 data, over 51 billion dollars in economic activity is realized, with over 17.1 billion dollars in wage and salary payments. It handled more than 34 million international passengers in 2019, breaking a record.

https://www.anewjfk.com/

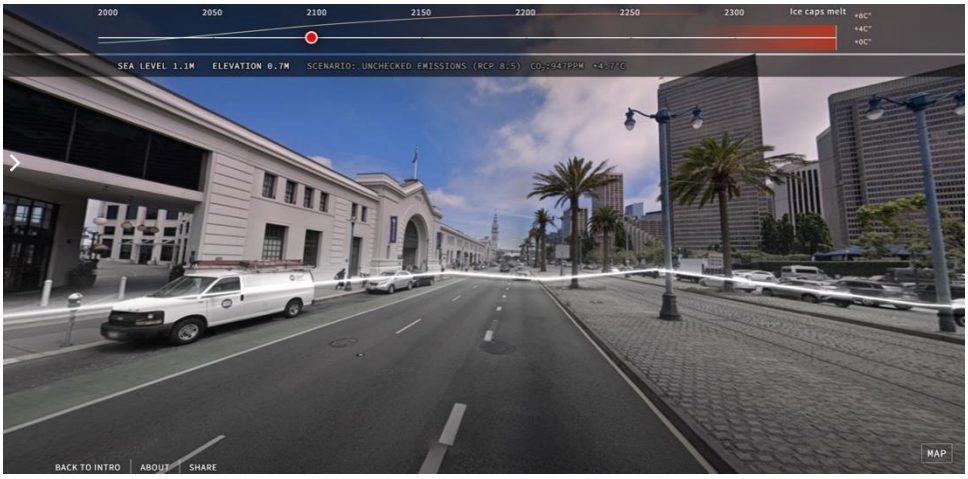
As the global sea level increases, it will be submerged in the near future. Given that other airports are in the area, this aviation facility will become unusable due to the same threat. When the labor and income it generates are considered, the United States will suffer a significant economic loss. The measures taken for JFK international airport are limited due to its proximity to the coast.

San Francisco Coastal Paradox Modeling-2150

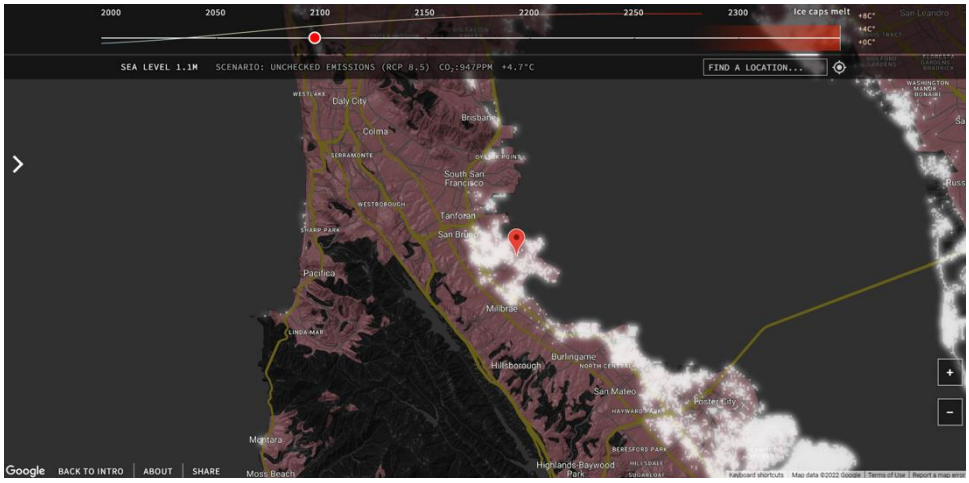
Since 2000, the global sea level has risen by 2.1 meters. 3.8 thousand people have migrated within a 5-kilometer radius of the highlighted region. Large-scale ecosystem deterioration is occurring globally. The CO^2 concentration is 1,470 ppm. The sea level is predicted to rise around 4 kilometers from the coast to the mainland.



Coastline Paradox.10. San Francisco Airport-Present



Coastline Paradox.11. San Francisco City Center-2150



Coastline Paradox.12. San Francisco International Airport-2150

SFO international airport handled 57,488,023 people in 2019, transporting 482,378 metric tons of cargo and performing 458,496 air traffic control operations. Domestic and foreign airline operations totaled 78,792. It has generated around $980 million in economic activity.

https://www.flysfo.com/media/facts-statistics/air-traffic-statistics/2019

It is the second busiest airport in California, after Los Angeles International Airport. The airport, which is located close to the sea, is one of the critical US airports at risk shortly. The floods in San Francisco, which is part of Silicon Valley, would affect many businesses and jobs, particularly in the technological sector. Apple, Google, Facebook, and Twitter are all established here.

Flood Risk from Global Sea Level Rising	2050	2100	2150	2200
Schipol Airport	**Risk**	**Risk**	**Risk**	**Risk**
JFK Airport	**No Risk**	**Risk**	**Risk**	**Risk**
San Francisco Airport	**No Risk**	**No Risk**	**Risk**	**Risk**
London Airport	**No Risk**	**No Risk**	**No Risk**	**No Risk**

Table.2. Airports Sea Level Height Of Airports Risk Table Between 2050-2200

The dates 2050 to 2200 were selected as the near, middle, and far futures, respectively. According to the table, Schipol Airport is the closest airport in jeopardy. John F. Kennedy international airport is predicted to be inundated later in 2100. The risk for the San Francisco airport begins at 2150. These processes have been exacerbated because these airports are located on the coastline. Except for London Airport, all of the airports in the table are submerged by 2200. The London airport is expected to continue operating because it is still in a secure place.

CONCLUSION

Airports selected for specific reasons were investigated as a result of the Coastline Paradox program-based investigations. Airports at risk now or in the not-too-distant future are classified using various criteria. The RCP8.5 approach provides estimated numbers of forced migration, rising global sea levels, and CO^2 measurements. Because of their location, these airports are among the most

important aviation centers. These airports were chosen to raise awareness of the severe dangers of global sea level rises due to climate change. Constructing airports of this size and capacity to catch up with the old demand is extremely tough.

At the airports investigated, several periods are offered. The primary goal is to demonstrate which airports are likely to be impacted shortly, medium-term, and long term. London Heathrow Airport, for example, is unlikely to be immediately affected soon. Indirect effects and consequences from other airports in the area, on the other hand, were mentioned.

It is calculated that a global sea-level rise of 1 cm goes in about 1 meter on land. If the climate crisis cannot be avoided, the disaster scenarios indicated above can occur in a considerably shorter time. To prevent short-term effects, various engineering projects are implemented. On the other hand, these projects will deteriorate and lose their efficacy as time passes, with ever-increasing consequences.

In the case of a crisis, the aviation industry has a high susceptibility rate. They are complex structures with 24-hour operating hours in various locations, high-tech products, skilled workforce requirements, showcase value for countries and economic benefits, and provide the first impression of the city or country in which they are located. The aviation industry has faced many crises, such as terrorism, diseases, and political conflicts. These crises have had a rapid effect on the whole aviation sector, which is a dynamic and global enterprise. On the other hand, the returns were as quick as the damage it inflicted. The aviation industry has been targeted many times by climate experts. As a result, people began to consider other means of transportation as an alternative. Pressures have started to appear on aviation authorities and countries to apply new legal obligations. However, the negative consequences of aviation on the climate crisis are decreasing day by day in line with technological developments. Once the future scenarios are considered, it is seen that the real major threat is the climate crisis-oriented new world order's negative impact on aviation.

The aviation industry, particularly airports, is in grave danger. Due to new airport construction projects, flight networks suited for new cities to be developed due to migration, unsafe and inefficient flights due to severe weather conditions, and substantial employment losses, the aviation sector faces a more risky future than it has ever encountered.

General aviation, which began with a desire to fly and has piqued humanity's interest since ancient times, has grown into a primary industry today. Developed societies can't plan without the aviation sector in the future. This awarenesses must be created to ensure the sector's future. Existing enterprises and structures should be protected, and new projects should be redesigned to compensate for the specific risks.

Compliance with Ethical Standard

Conflict of Interest: The authors declare that there is no conflict of interest.

Ethics Committee Permission: Ethics committee approval is not required for this study

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