CLIMATE CHANGE AND HEALTH IN MALAYSIA:

IMPLICATIONS AND CHALLENGES

Thematic Working Group (TWG) 10
– Environmental Health Expert
National Environmental Health Action Plan (NEHAP)
August 2024

National Environmental
Health Action Plan
(NEHAP) Malaysia

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List of Selected Abbreviations

AMP	Adaptation and Mitigation Program
CMIP5	Coupled Model Intercomparison Project Phase 5
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DID	Department of Irrigation and Drainage
GDP	Gross Domestic Product
GHG	Green House Gases
GMSL	Global Mean Sea Level
IPCC	Intergovernmental Panel on Climate Change
MyCAC	Malaysian Climate Action Council
MET Malaysia	Malaysian Meteorological Department
NADMA	National Disaster Management Agency
NAFFWS	National Flood Forecasting and Warning System
NAHRIM	National Water Research Institute of Malaysia
NAP	National Adaptation Plans
NSC	National Security Council
NDC	Nationally Determinant Contributions
NSCCC	National Steering Committee on Climate Change
RCPs	Representative Concentration Pathways
SLR	Sea level rise
UNEP	United Nations Environmental Program
UNFCC	United Nations Framework Convention on Climate Change

Preamble

Climate change in Malaysia is a growing issue that affects facets of the country's environment, society and economy. Southeast Asia, where Malaysia is situated is increasingly facing rising temperatures that are giving the country warmer weather on average, as well as changes in rainfall patterns and more extreme weather like floods and droughts. They pose risks to its biodiversity, agriculture and coastal communities. The country is also dealing with problems including rising sea-levels along a vast coastline and the disruption of natural ecosystems. While steps to mitigate its impact, through the introduction of policies on deeds which reduce greenhouse gas emissions and seek greater resilience in Malaysia as well as best efforts are worthwhile, it is a very complicated puzzle that needs ongoing attention to fix.

This assertion is supported by the range of commitments that Malaysia has made under different components and workstreams of the Paris Agreement, supplemented by a collection of strategic national policies and institutional arrangements for addressing both climate change mitigation as well as adaptation. Important steps also included the establishing of Nationally Determined Contributions (NDC), setting reduction targets and adaptation plans. Other country such as the Philippines has repeatedly faced the threat of a changing climate, with disasters like the extended El Niño drought in 1998 and recent heat waves serving as reminders that it is one of country´s most vulnerable to extreme weather. MET Malaysia is an agency under the Ministry providing information on weather phenomena, climate issues and severe climatic events to assist in implementation of policy. The rise in vector-borne diseases and heat-related illnesses calls for both immediate actions by society and long-term, strategic efforts that bring together the government, private sector, and community.

This document is intended to provide responses to global commitment over climatic challenges and to share more of the insights that can help inform the policy makers, stakeholders and public in general with a hope to make AMP approach for climate action much more informed and proactive. Through documenting the progress made in Malaysia and pointing to areas where improvement can still be achieved, it is intended that this book will provide some input towards better climate policies which are more effective (i.e. reduced exposure) and sustainable (containing high frequency / low severity events)—policies which enhance resilience rather than impact on the environment further downstream.

NEHAP Secretariat would like to express appreciation and gratitude to TWG 10: Environmental Health Experts, chaired by Prof. Dr. Jamal Hisham Hashim, for leading the development of this document, and to all those who have contributed directly or indirectly by providing input and feedback. We hope this document will benefit all stakeholders in protecting the environment.

1. Introduction

Climate change is currently one of the global environmental health issues that is threatening the health and survival of all living things including environmental health, with deteriorating changes with regards to the quality of air, water and food in the regions where populations live, work and play. These changes also affect myriads of animals, insects and plants on this planet, affecting continents and countries.

2. What is Climate Change?

Climate change refers to long-term shifts in temperatures and weather patterns of the Earth. Since the 1800s, human activities such as the burning of fossil fuels (coals, oil and gas) have been the main drivers for climate change. These activities generate greenhouse emissions that traps the sun's infrared heat near the Earth's surface and increase the Earth's surface temperatures. Two main greenhouse gases are carbon dioxide (CO_2) and methane (CH_4) which are contributed by the combustion of gasoline in motor vehicles or burning of coal. The main sectors which contribute to increasing greenhouse gases are energy, industry, transport, buildings, agriculture and land use[1].

2.1 Causes of climate change

Climate change is attributed directly or indirectly to human activities that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods[2] (Figure 1). Human activities such as the burning of fossil fuels and the related use of coal and petroleum, producing large concentrations of greenhouse gases and black carbon (power generation, industry, transportation and constructions). Long term data showed strong correlations between CO_2 levels and the global ambient temperature, as well as the sea level rise, melting of polar ice and glacier, and expansion of species distribution. The data showed the increasing temperature trends began in the early 19th century (Figure 2). This increasing temperature affects all components of the Earth's systems and due to that, the world is facing more extreme weather events as well as sea level rise. This, in turn will affect the ecosystems of the world, and disrupt the water resources, food security as well as human, animal and ecosystem health.

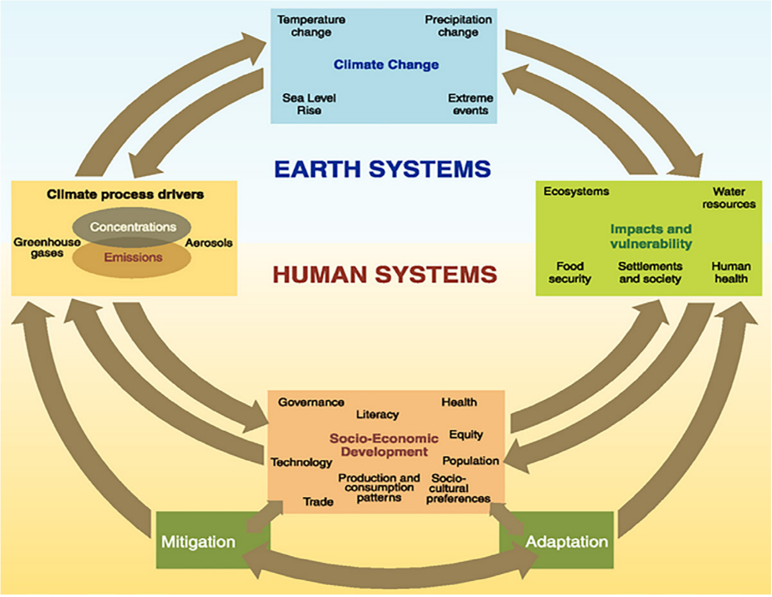

Figure 1: Schematic framework of anthropogenic climate change drivers impacts and responses.
Source: Intergovernmental Panel on Climate Change, IPCC (2007)[3].

1 United Nations Climate Action. Available at https://www.un.org/en/climatechange/what-is-climate-change. Accessed on 23 March 2024.

2 United Nations Framework Convention on Climate Change (UNFCC). (1992). Available at https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf. Accessed on 15 September 2022.

3. Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988. The objective of the IPCC is to provide governments at all levels with scientific information by preparing regular assessment reports on climate change and communicating these assessments to the Convention[3].

The Synthesis Report (SYR) distils and integrates the findings of the three Working Group contributions to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), which is the most comprehensive assessment of climate change undertaken thus far by the IPCC: Climate Change 2013: The Physical Science Basis; Climate Change 2014: Impacts, Adaptation, and Vulnerability; and Climate Change 2014: Mitigation of Climate Change[4]. The SYR also incorporates the findings of two Special Reports on Renewable Energy Sources and Climate Change Mitigation (2011) and on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (2011).

The timing of the SYR, which was released on 2nd November 2014 in Copenhagen, was crucial. Policymakers met in December 2014 in Lima at the 20th Conference of Parties under the United Nations Framework Convention on Climate Change (UNFCC), to prepare the groundwork for the 21st Session in 2015 in Paris, when they have been tasked with concluding a new agreement to deal with climate change.

3.1 Assessment reports

The IPCC publishes comprehensive Assessment Reports (AR) on the status of scientific, technical, and socioeconomic knowledge regarding climate change, its impacts and future hazards, as well as solutions for slowing down the rate of change. It also publishes Special Reports on issues agreed upon by its member nations, as well as Methodology Reports that provide standards for greenhouse gas inventory preparation. The first AR was published in 1990 and concluded that “emissions resulting from human activities are substantially increasing atmospheric concentrations of greenhouse gases. These increases will enhance the greenhouse effect, resulting on average “an additional warming of the Earth’s surface”. Based on the studies conducted, the panel has concluded that the human influence has been the dominant cause of the warming trend since the mid-20th century.

a) Assessment Report 5 (AR5) and Assessment Report 6 (AR6)

The Fifth Assessment Report (AR5) is a part of a series of reports from the IPCC and was released over the course of 2013 – 2014. An additional synthesis report (SR) was published in November 2014. The AR5 includes a consistent evaluation and assessment of uncertainties and risks; integrated costing and economic analysis; regional aspects; changes, impacts and responses related to water and earth systems, the carbon cycle including ocean acidification, cryosphere and sea level rise; as well as treatment of mitigation and adaptation options within the framework of sustainable development. Other aspects of climate change covered in the AR5 include direct impacts of climate change on natural systems, as well as both direct and indirect impacts on human systems, such as human health, food security and security of societal conditions.

There are several Headlines Statements of AR5 which included:

- Observed Changes and their Causes; human influence on the climate system is clear and the climate changes does impact the human and natural systems.

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[3] Intergovernmental Panel on Climate Change (IPCC). (2007). IPCC Fourth Assessment Report: Climate Change 2007. Available at: https://archive.ipcc.ch/publications_and_data/ar4/syr/en/figure-i-1.html. Accessed on 8 April 2022.

[4] Intergovernmental Panel on Climate Change (IPCC). (2014). IPCC Fifth Assessment Report: Climate Change. Available at: https://www.ipcc.ch/sr15/download/#chapter. Accessed on 15 August 2021.

- Future Climate Changes, Risk and Impacts; continued emission of greenhouse gases will cause further warming and long-lasting impact in the climate system and irreversible impacts for people and ecosystems, which requires substantial, sustained reductions in greenhouse emissions together with adaptation action.
- Future Pathway for Adaptation, Mitigation and Sustainable Development; complementary strategies of adaptation and mitigation for reducing and managing the risks of climate change and contributes to climate-resilient pathways for sustainable development.
- Adaptation and Mitigation; the effectiveness of implementation depends on policies and cooperation from all scales and can be enhanced through integrated responses that links adaptation and mitigation with other societal objectives.

The IPCC's AR5 provided the scientific input into the Paris Agreement, which aims to strengthen the global response to the threat of climate change by holding the increase in the global average temperature to well below 2ºC above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5ºC above pre-industrial levels[5].

Following a decision on the adoption of the Paris Agreement, the COP to the UNFCC invited the IPCC to provide a special report in 2018 on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways. The Panel accepted the invitation, and a Special Report on global warming in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty was produced by the IPCC. It is a comprehensive assessment of our understanding of climate change to help step up action to respond to climate change, achieve climate-resilient development and foster an integrated approach to the provision of climate services at all levels of governance.

b) Assessment Report 6 (AR 6)

The Sixth Assessment Report (AR6) is the latest in a series of reports from the IPCC and was released in 2021[6]. The AR6 provides a detailed understanding of the current state of the climate, changes of climate, the role of human influence, the state of knowledge on climate futures, relevant climate information based on various regions and sectors, and limiting human-induced climate change.

Key findings from AR 6 include:

- Human influence has contributed to the warming of the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.
- Human activities have warmed the climate at an unprecedented rate, for at least the last 2000 years. Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. The AR6 report has strengthened the effects and correlates heatwaves, heavy precipitation, droughts, and tropical cyclones, and attributes it to human influence.
- Global surface temperature will continue to increase until at least mid-century under all emissions scenarios. Global warming is expected to exceed 1.5°C and 2°C by mid of the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades.

[5] United Nations Framework Convention on Climate Change Paris Agreement (2015). Available at: https://unfccc.int/sites/default/files/english_paris_agreement.pdf. Accessed on 13 March 2022.

[6] Intergovernmental Panel on Climate Change (IPCC). (2021). Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu & B. Zhou (eds.)] Accessed on 20 April 2022.

Proposed key findings from earth.org (https://earth.org/ipcc-assessment-report/):

The Intergovernmental Panel on Climate Change (IPCC) of the United Nations is the foremost entity devoted to advancing scientific knowledge about anthropogenic climate change. Established in 1988, the agency carries out the biggest and most internationally recognised peer-reviewed process in the scientific community on climate change. The premier authority on climate change has recently wrapped up its sixth assessment, following the March 2023 release of its Synthesis Report (AR6). The 8,000-page IPCC Sixth Assessment Report (AR6) is the most comprehensive and ambitious study ever conducted by the intergovernmental body and the "starkest warning yet" to be delivered.

The Sixth Assessment Report is the last of six major comprehensive reports released by Intergovernmental Panel on Climate Change (IPCC) since 1988. IPCC has published 14 specific reports on particular topics inclusive of ocean and cryosphere, land use, and renewable energy.

Peer-reviewed sources are the foundation of the IPCC's body of work. The Panel assesses scientific papers and independent findings from other scientific bodies and entities. Through this kind of research, the IPCC carries out three distinct working groups:

- Working Group I: Physical science basis of climate change.
- Working Group II: Climate change impact, adaption, and vulnerability.
- Working Group III: Mitigation of climate change

It is estimated that over 8,000 scientists from 195 different countries have contributed to the IPCC reports throughout the years. The collective efforts of governments, the private sector, civil society, and academia are vital to the approval, adoption, and acceptance phases of each published report.

Common themes are found in the potential destruction caused by rising greenhouse gases (GHG), including rising global temperatures, extreme weather events (droughts, floods etc), and rising sea levels. Fortunately, it is all gloom and doom. There is still time, but we must take immediate steps now to limit global warming to 1.5°C, the critical threshold agreed upon by 195 countries with the 2015 Paris Agreement. That is only possible through immediate actions to curb greenhouse gas emissions, with the intent of halving emissions by 2030.

As stated in the Sixth Assessment Report: "The magnitude and rate of climate change and associated risks depend strongly on near-term mitigation and adaptation actions, and projected adverse impacts and related losses and damages escalate with every increment of global warming."

8 Key findings from the IPCC Sixth Assessment Report:

1. **Climate change is happening, it is the result of reckless human activities and a threat to human and natural systems**

   The IPCC AR6 states that: "Human-caused climate change is a consequence of more than a century of net GHG emissions from energy use, land-use and land use change, lifestyle and patterns of consumption, and production."

   For decades, humans have been burning fossil fuels to produce energy needed to manufacture things like cement, iron, steel, electronics, plastics, clothes and other goods, and deforestation at unprecedented rates to free up land for urban development and agricultural land releasing large amounts of greenhouse gases into the atmosphere, which trap heat and cause global temperatures to rise.

   Global fossil fuel consumption has more than doubled in the last 50 years, as countries around the world aim to improve their standards of living and economic output. In 1971, the world consumed approximately 4 billion metric tons of oil. In 2018, the number surpassed 8 billion metric tons. The rate of deforestation has also been increasing since 2015, with an estimated 10 million hectares of primary forest being cleared each year. Current agricultural practices are not sustainable in the long term, as they lead to a range of environmental problems, such as soil erosion, water pollution, and biodiversity loss. The greenhouse gas emissions associated with these practices are an issue as well (Figure 2). Around 25% to 30% of global emissions nowadays come from our food systems and agricultural products.

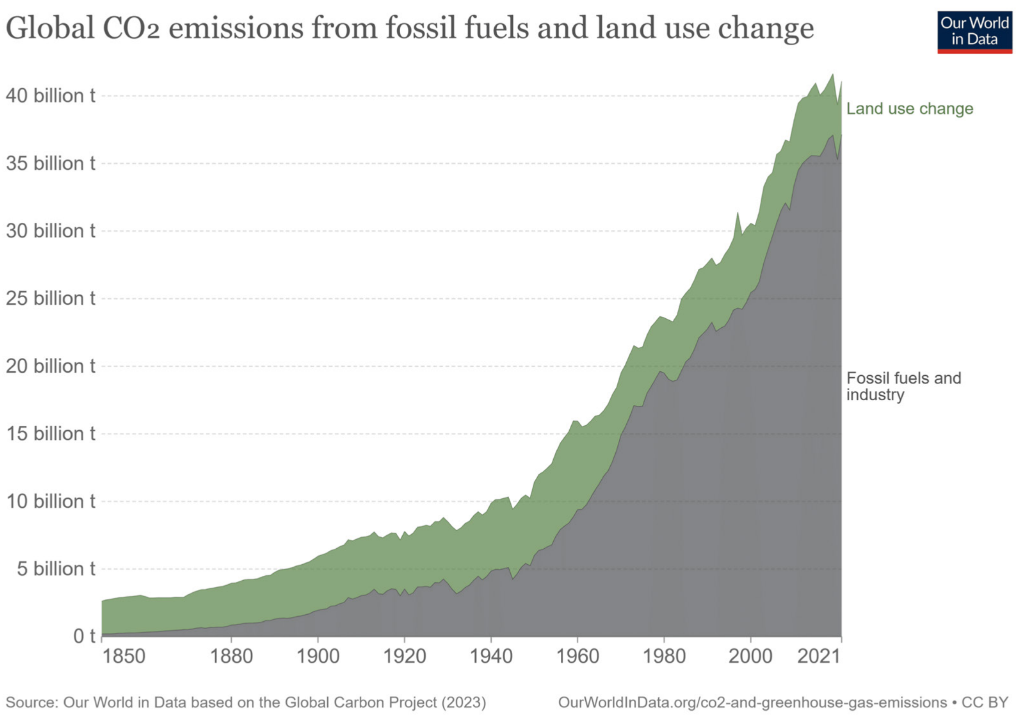


Figure 2: Carbon dioxide (CO_2) emissions from fossil fuels and industry.
Source: Our World in Data (2023)[7].

2. Global temperatures are rising, glaciers are melting, and sea levels are rising

The average global temperature has increased by over 0.8ºC since the pre-industrial era and is projected to keep rising in the coming decades. As the climate heats up, rainfall patterns change, evaporation increases, glaciers melt, and sea levels rise. Global surface temperature has increased significantly since 1970 than in any other 50-year period over at least the last 2,000 years.

The likely range of total human-caused global surface temperature increase from 1850-1900 to 2010-2019 is 0.8 ºC to 1.3ºC, with a best estimate of 1.07ºC (Figure 3). Sea-level rise projections show that, even if the world follows a low greenhouse gas pathway, the level of sea rises globally will continue to rise up to about 0.7 meters by the end of this century. This risks the displacement of one in every 10 people on the planet and triggers massive economic, social, and cultural disruptions worldwide.

The rate at which glaciers are disappearing has risen 57% since the 1990s, and under current warming trends, two-thirds of Earth's glaciers may vanish by 2100. The global mass of glaciers decreased by an average of 0.42 metres of water equivalent per year between 2000 and 2019. Additionally, the rate of melting has increased sharply, with an average loss of 0.75 meters of water equivalent per year in the same timeframe with potential catastrophic consequences for hundreds of millions of people worldwide.

[7] Our World in Data. (2023). Available at: https://ourworldindata.org/grapher/co2-emissions-fossil-land. Accessed on 5 February 2023.

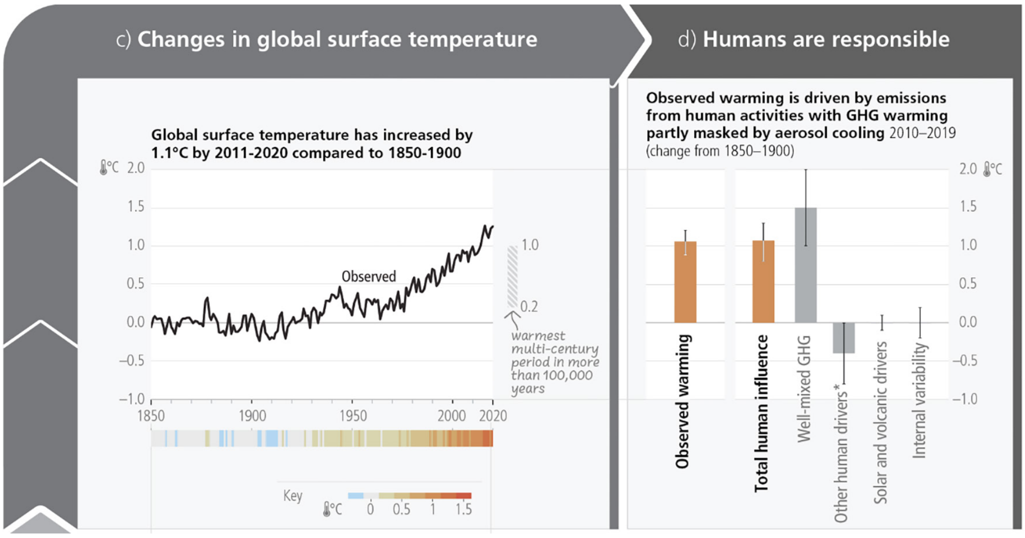


Figure 3: Humans are responsible for changes in global surface temperature. Source: IPCC-AR6-SYR[8].

3. The frequency and intensity of extreme weather events are increasing

Figure 4 illustrates human induced extreme weather events inclusive of floods, heatwaves, droughts, and tropical cyclones from 190 extreme weather events. These events are capable of causing huge loss of life and properties. The scientific community unanimously agrees that global warming is exacerbating the intensity of these events as it increases the evaporation of surface waters into the atmosphere, affecting rain patterns worldwide. Several studies provide undeniable evidence that rising global temperatures have made event such as the Horn of Africa drought and last year's record-breaking heatwaves in the Northern Hemisphere up to 100 times more likely. More than half of the global population faces severe water scarcity for at least one month each year, and by 2050, droughts might affect up two-thirds of the world's population.

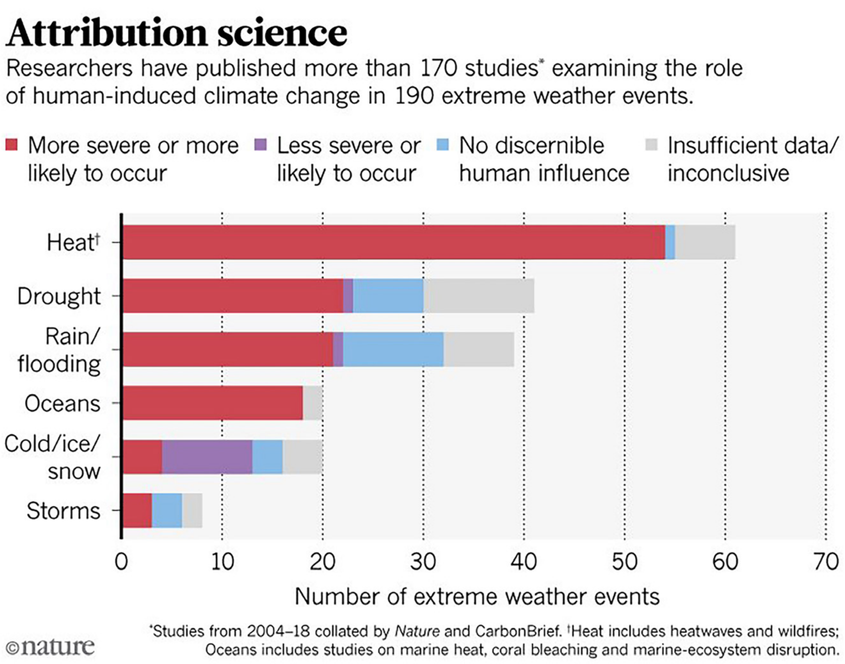


Figure 4: The role of anthropogenic climate change in extreme weather events. Source: Earth.Org[9].

8 IPCC-AR6-SYR. Available at: https://www.ipcc.ch/ar6-syr/ Accessed on: 5 February 2023.

9 Earth. Org. Available at: https://earth.org/ipcc-assessment-report/ Accessed on: 5 February 2023.

4. **Oceans acidification is accelerating, biodiversity is decreasing, and water is becoming increasingly scarce**

   Ocean acidification has increased by 30% since pre-industrial times and is expected to continue rising in the future. This sharp increase in acidity has devastating impacts on marine ecosystems, leading to decreases in biodiversity and the collapse of fisheries.

   Biodiversity is decreasing due to habitat destruction, overfishing, and of course, climate change. The rate of species extinction is estimated to be 100 to 1,000 times higher than the natural background rate. This rate refers to the rate of carbon dioxide concentration in the atmosphere before industrialisation, estimated at around 280 parts per million (the current rate around 420 ppm).

   If global warming reaches 4ºC, findings in AR6 suggest that around 4 billion people are projected to experience water scarcity with additional adaptations (food insecurity, technological improvements, etc.). Currently, roughly half of the world's population is already experiencing severe water scarcity for at least some part of the year due to a combination of climatic and non-climatic drivers.

5. **Climate Change is exacerbating existing inequalities**

   Climate change is exacerbating inequalities, as vulnerable communities and developing countries are disproportionately impacted by its effects. For example, those living in poverty are more likely to be affected by extreme weather events, such as floods and droughts, due to a lack of access to resources, health services and adequate infrastructure. Despite their almost insignificant contribution to global greenhouse gas emissions, households in the bottom 50% of incomes are already being disproportionately affected by the effects of climate change and will continue to be the most impacted in the future. Additionally, those living in low-lying coastal areas are more likely to be affected by sea level rise (Figure 5).

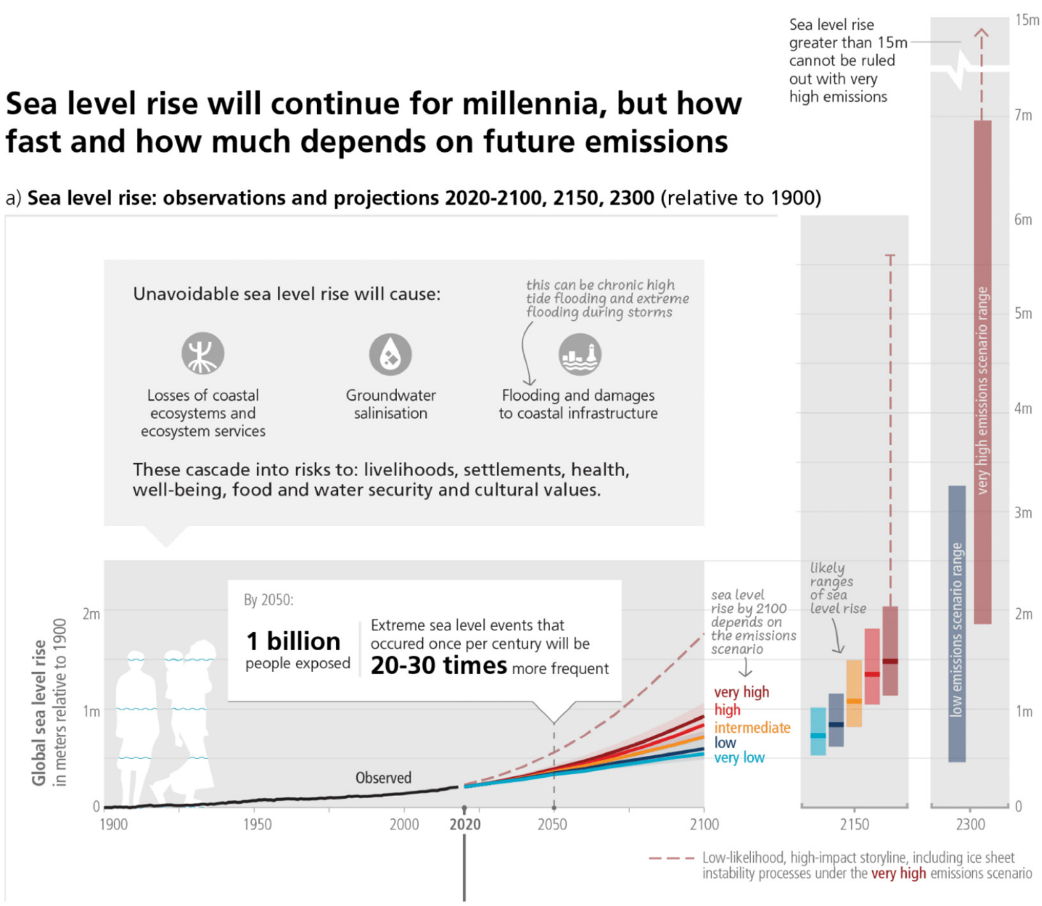


Figure 5: Sea level rise will continue for millennia, depending on future emissions. Source: IPCC-AR6-SYR[8].

6. **The global economy is vulnerable to the impacts of climate change**
The destruction brought about by extreme weather events such as floods and can disrupt global supply chains, leading to huge economic losses (Figure 6). If current trajectories of greenhouse gases emission do not meet the Paris Agreement and 2050 net-zero emission targets, the world could risk losing around 10% of its total economic value. With risks of global average temperature increase surpassing 3ºC by mid-century, we could see as much as 18% of global GDP eroded. Climate-related risks for natural systems and humans, including food and water insecurity, land degradation, spread of diseases, and conflicts, are higher in a 1.5ºC warming scenario than at present.

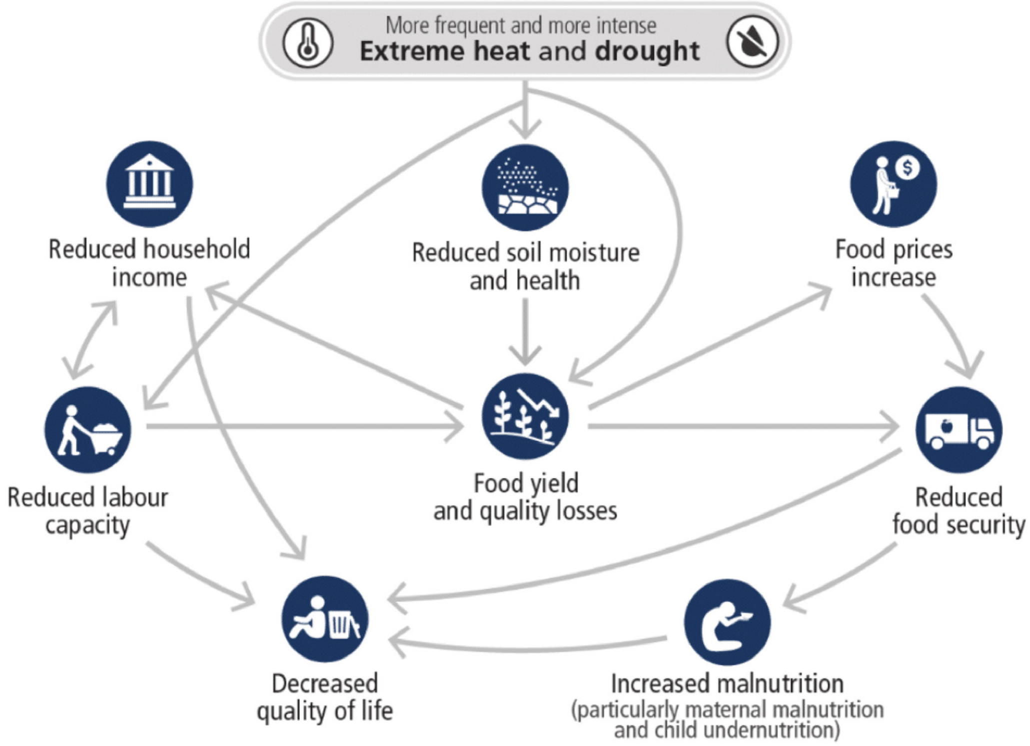


Figure 6: Feedback loop of more extreme heat and drought.
Source: IPCC-AR6-SYR[8].

7. **We have options in all sectors to at least halve emissions by 2030**
According to IPCC Working Group III Co-Chair Priyadarshi Shukla: "Having the right policies, infrastructure and technology in place to enable changes to our lifestyles and behaviour can result in a 40-70% reduction in greenhouse gas emissions by 2050."

Adaptation strategies are necessary to reduce the impacts of climate change, such as increasing the resilience of infrastructure and communities, improving access to clean water and sanitation, and improving coastal infrastructure to protect low-lying areas from sea level rise. Additionally, mitigation strategies are needed to reduce greenhouse gas emissions, such as transitioning to renewable energy sources, implementing carbon pricing, and scaling up carbon capture technologies. The IPCC also discusses that many countries have already implemented carbon pricing systems within their borders. 57 nations around the world have implemented or scheduled implementation of carbon pricing initiatives that cover 11 gigatons of carbon dioxide, which is estimated to be around 20% of global greenhouse gas emissions. Carbon prices in these initiatives range from $1 to $127/ton of carbon dioxide, and the majority of emissions covered are priced at more than $10/ton (Figure 7

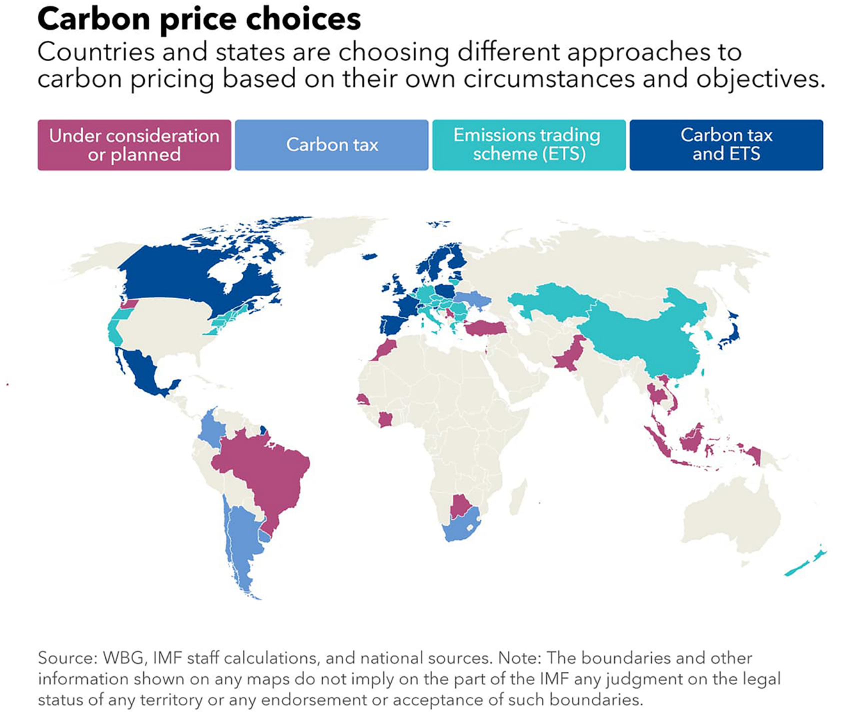


Figure 7: Expansion of carbon pricing schemes.

So far, 46 countries are pricing emissions through carbon taxes or emissions trading schemes (ETS) and others are considering it. Source: International Monetary Fund, IMF (2022)[10].

8. International cooperation is required to tackle climate change

International cooperation and actions are necessary to tackle climate change, as climate change is a global problem that requires global solutions. This includes strengthening existing international agreements, such as the Paris Climate Accord, and developing new initiatives and policies to reduce greenhouse gas emissions. Additionally, countries must work together to provide support and assistance to vulnerable communities, such as those affected by extreme weather events and sea level rise.

As mentioned repeatedly in the IPCC AR6, limiting global temperature rise to 1.5C is still possible, though immediate action is needed. The global greenhouse gas emissions have to be halved by 2030, and reach net-zero emissions around mid-century. Additionally, all stakeholders, including governments, the private sector, civil society and individuals, must take action to help reduce the risks of climate change and provide resources to vulnerable communities. The UNFCCC has been successful in gathering near-universal participation, leading to the development of climate-related policies and targets on both the national and sub-national levels. These policies, known as Nationally Determined Contributions (NDCs), require countries to outline their ambitions in terms of climate action and support, as well as increasing transparency of these initiatives.

3.2 Malaysia: Major milestones on climate change

The United Nations Framework Convention on Climate Change (UNFCCC), one of the three Rio Conventions was established to achieve the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system. At COP 21 in Paris, on 12 December 2015, Parties to the UNFCCC agreed to maintain the average global temperature rise to not more 2 degrees Celsius until the end of this century

[10] International Monetary Fund (IMF). (2022). Available at: https://www.imf.org/en/Blogs/Articles/2022/07/21/blog-more-countries-are-pricing-carbon-but-emissions-are-still-too-cheap. Accessed on 5 February 2023.

and in the long run increase efforts to limit global average temperature rise to not more than 1.5 degrees Celsius compared to pre-industrial era levels. As a party under the UNFCCC, Malaysia has ratified the UNFCCC since 1994, and is committed to fulfil its obligation to ratify the protocols and agreement under the Convention (Figure 8).

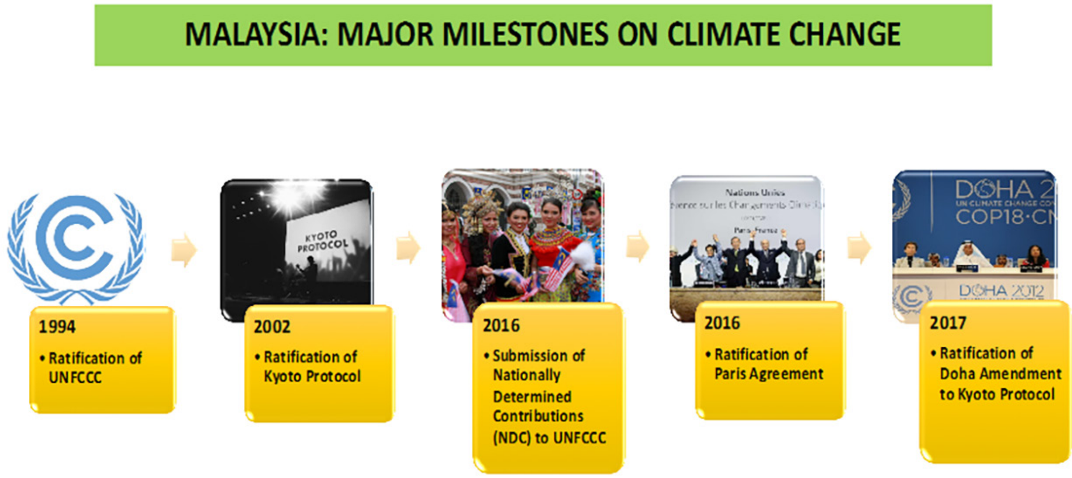


Figure 8: Major milestones on climate change by Malaysia.

4. Malaysia's Climate Change Policy and Response

4.1 National policy on climate change

The main policy to guide Government agencies, industry, communities and other stakeholders in addressing the challenges of climate change in the context of effective and holistic manner is provided in the National Policy on Climate Change, which was approved by the Cabinet in 2009. The policy recognised to put the need for both mitigation and adaptation to be carried out in a balanced manner where national responses that consolidate economic, social and environmental development goals are mainstreamed based on the following five principles:

- Development on a sustainable path: To integrate climate change responses into national development plans to fulfil sustainable development.
- Conservation of environment and natural resources: To strengthen the implementation of climate change actions on environmental conservation and sustainable use of natural resources.
- Coordinated implementation: To incorporate climate change considerations into the implementation of development programmes at all levels.
- Effective participation: To improve participation of stakeholders and major groups for effective implementation of climate change responses.
- Common but differentiated responsibilities and respective capabilities: International involvement on climate change will be based on the principle of common but differentiated responsibilities and respective capabilities.

4.2 Institutional arrangements

Institutions in Malaysia support three key areas of climate change action: policy making, development planning and implementation, and guidance and reporting (Figure 9).

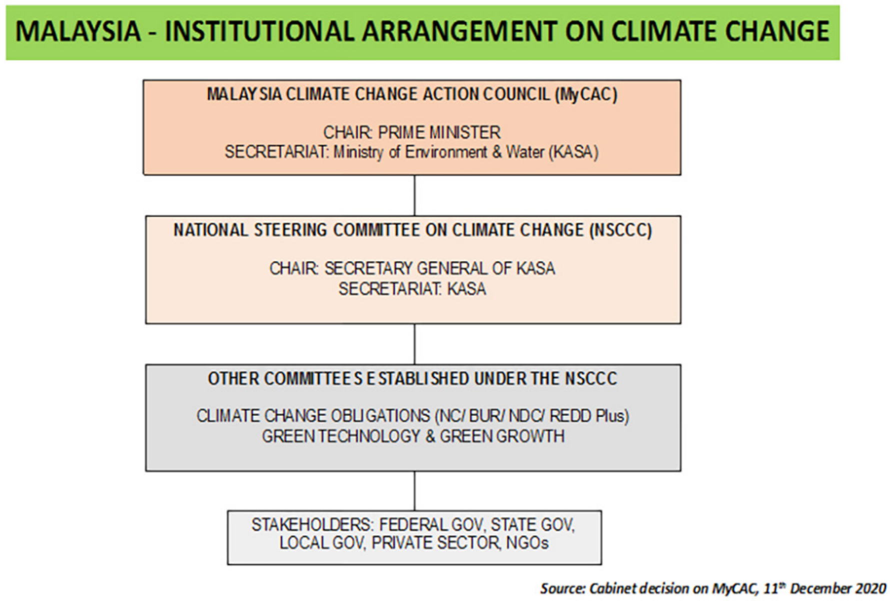


Figure 9: Institutional arrangement on climate change in Malaysia.

The key ministries for climate change had undergone restructuring, where in March 2020, a restructuring exercise occurred where they were reconfigured as the Ministry of Environment and Water (KASA) and Ministry of Energy and Natural Resources (KeTSA)[11]. The national focal point to the UNFCCC thus resides under KASA[12].

With the current institutional arrangement, the Malaysia Climate Change Action Council (MyCAC) will be the highest body at the political level on climate change policy governance. At the working level, the National Steering Committee on Climate Change (NSCCC) is an apex body to drive policy coordination and implementation at the national level. There are also several policies and technical committees established under the NSCCC and focusing on specific issues such as the preparation of national reports, preparation and updating the NDC, and the forestry initiative (REDD Plus).

5. National Determined Contribution (NDC)

The government of Malaysia is required to meet the mitigation targets stated in the Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in November 2015 (Figure 10).

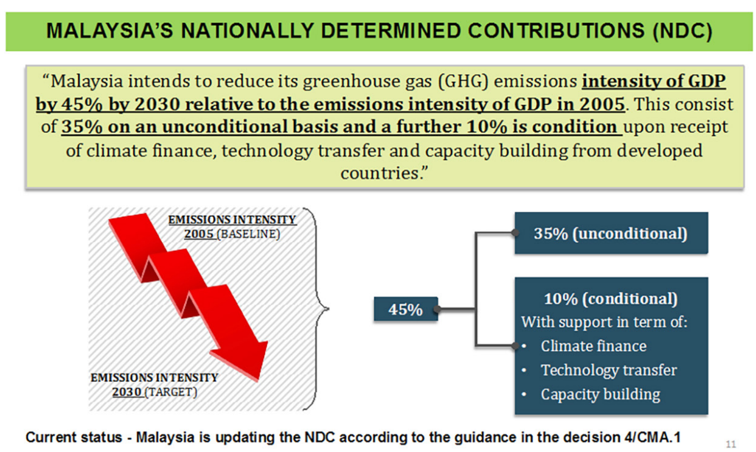


Figure 10: Malaysia's Nationally Determined Contributions.

11 Malay Mail. (2020). Environment Ministry Rebranded as Ministry of Environment and Water. Available at: https://www.malaymail.com/news/malaysia/2020/04/02/tuan-ibrahim-environment-ministry-rebranded-as-ministry-of-environment-and/1852838. Accessed on 16 April 2020.

12 Kementerian Alam Sekitar dan Air. Pelan Kelestarian Alam Sekitar. Roadmap KASA. Available at: https://www.kasa.gov.my/pelan-kelestarian-alam-sekitar-malaysia. Accessed on 2 February 2022.

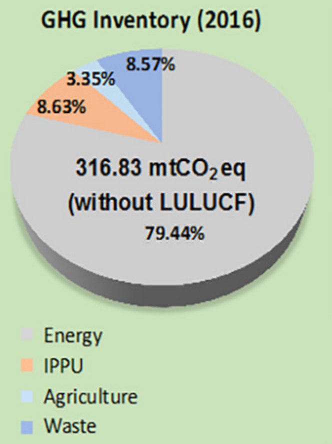
On that convention, Malaysia is committed to reduce by 45% of national GHG emissions per GDP by 2030, relative to its emissions intensity in 2005. This target would encompass a 35% reduction on an unconditional basis, and a further 10% reduction subject to receipt of climate financing, technology transfer and capacity building from developed counties. The government of Malaysia under KASA is progressing to update the technical information which is contained in the NDC, according to the guidance of Decision 4/CMA.1.

6. Greenhouse Gas Emission

The government of Malaysia reports the latest GHG inventory (2016) in the Malaysia's 3rd Biennial Update Report (BUR-3) to the UNFCCC (Figure 11). Although the energy sector accounts as the highest emitting sector (251.7 mtCO2 eq), Malaysia is blessed with GHG removals from land use, land use change and forestry (LULUCF) which removes 259.15 mtcCO2eq of GHG emissions. This signifies the importance of forests in Malaysia for GHG mitigation as Malaysia still holds 55.3% of forest cover.

GHG INVENTORY (2016)

Sector	Million tonne CO_2 equivalent ($mtCO_2$ eq)
Energy (including transport)	**251.7**
Industrial processes and product use	**27.35**
Agriculture	**10.63**
LULUCF (emissions only)	17.80
LULUCF (removals)	- 259.15
LULUCF (net emissions)	**- 241.35**
Waste	**27.16**
GHG emissions (without LULUCF)	**316.83**
GHG emissions (with LULUCF)	**75.49**



Source: Malaysia's BUR-3 to the UNFCCC, 2020

9

Figure 11: Green House Gas Inventory (2016). Source: Malaysia's BUR-3 to the UNFCC (2020)[13].

7. Malaysia Climate Change Policy Response

Ministry of Natural Resources and Environmental Sustainability, NRES (formerly known as KASA) is in the midst of scaling up its efforts towards the obligations under the Paris Agreement and UNFCCC. The government of Malaysia under NRES is putting up enormous efforts to address climate change at various levels such as at the national and sub-national levels by mainstreaming climate change and low emissions development in the national development agenda. Concurrently, the government also has several works on the ground, in particular:

- Revision of National Climate Change Policy (2009).
- Developing the climate change legal framework.
- Developing new carbon pricing and market mechanism policy.
- Development of NDC Roadmap (2021- 2050).
- Development of the National Adaptation Plan (NAP).
- Formulating Long Term Low Emissions Development strategy (LT-LEDS).
- GHG Information Management System (GHG-IMS) and Database.
- Domestic Measurement, Reporting and Verification Platform Systems.
- Projections (TIMES Modelling) – for monitoring and tracking of NDC implementation.

[13] Malaysia's BUR-3 to the UNFCC. (2020). Available at: https://unfccc.int/sites/default/files/resource/MALAYSIA_BUR3-UNFCCC_Submission.pdf. Accessed on 5 February 2023.

8. Historical Climate Events in Malaysia

Greenhouse gases (GHG) trap the heat in the atmosphere, which in turn can cause global warming and climate change. Monitoring of global greenhouse gases in Malaysia has been conducted more than a decade at the Danum Valley Global Atmospheric Watch (GAW) Station, Sabah (Figure 12). The Danum Valley global GAW Station is situated in a Class 1 Protected Forest Reserve, and therefore is synonymous with the importance of equatorial forest regions, such as those found in Borneo, as global sinks for GHG[14].

Generally, the global trends of CO_2, CH_4, N_2O (Nitrous Oxide) and SF_6 (Sulphur Hexafloride) are increasing when the measurements at both Mauna Loa and Danum Valley GAW stations are compared. Comparatively higher concentrations at the Danum Valley GAW Station for CH4 are due to the forested environment of the station being surrounded by palm oil agricultural activity. A similar pattern of all four CO_2, CH_4, N_2O and SF_6, reducing and increasing during the Boreal winter and summer monsoons respectively, at the Danum Valley GAW Station is demonstrated in Figure 12, when the

Seasonal concentrations of all four GHGs, CO2, CH4, N2O and SF6 demonstrate reduction and increment during the Boreal winter and summer monsoons respectively, at the Danum Valley GAW Station (Figure 12). The highest concentrations during the months of December, January and February demonstrate significance of the northerly winds in transporting of CO_2, CH_4, N_2O and SF_6 into Northeastern Borneo. The lowest concentrations are recorded during July, August, and September, coinciding with the period during which the southerly component is significant, and northerly penetration into Northeast Borneo is at its weakest.

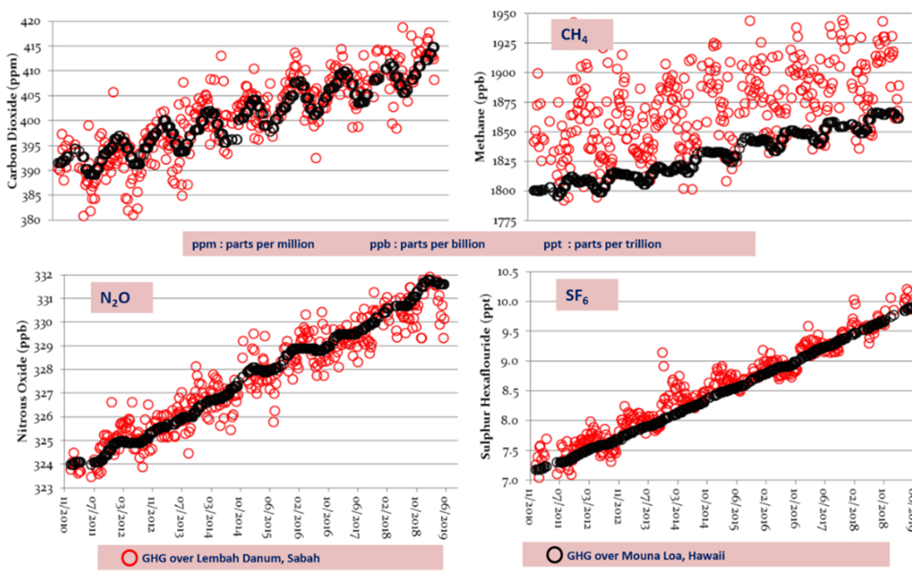


Figure 12: Comparison of GHG observations over Lembah Danum, Sabah and Mouna Loa, Hawaii from the years 2010 to 2019. The trend of increased atmospheric concentrations of CO_2, N_2O and SF_6 is consistent between the Lembah Danum, Sabah and Mouna Loa, Hawaii except CH_4. Lembah Danum CH_4 showed higher readings than expected due to agricultural activities over the region.

However, during El Nino driven peatland forest fires, such as during 2014 and 2015, higher emissions of CO_2 have been observed in Borneo[15]. Therefore, it was not surprising to observe a significant increase of CO_2 at Danum Valley during the above period, as demonstrated in Figure 12. This rate of increase observed was higher than the regular rate of increase experienced due to global emissions of CO_2. Southerly winds driven CO_2 originating from forest fires in Kalimantan during the Boreal Southwest Monsoon of 2014 and 2015 had caused the above anomaly.

14 Nomura, S., Mukai, H., Terao, Y., Takagi, K., Mohamad, M. & Jahaya, M.F. (2018). Evaluation of forest CO_2 fluxes from sonde measurements in three different climatological areas including Borneo, Malaysia and Iriomote and Hokkaido, Japan. *Tellus B* 70(1): 1-19.

15 Shiraishi, T., Hirata, R., Masato, H. & Takahashi, H. (2023). Carbon dioxide emissions through land use change, fire and oxidative peat decomposition in Borneo. *Nature* 13:13067.

Comparing the seasonal variations observed at the Mauna Loa and Danum Valley GAW stations, the effects of the Boreal winter and summer monsoons are relatively similar only for CO_2. Both N_2O and SF_6 in the atmosphere are nearly entirely anthropogenic. The main sources of N_2O and SF_6 are from power plants and the industrial sector. The temporal variation responses of the boreal monsoons towards CH_4 concentrations are relatively consistent for both GAW stations above. Nevertheless, with the agriculture sector driving the economy in eastern Sabah and northern Kalimantan, as expected typical concentrations and seasonal variations in CH_4 are much larger at Danum Valley compared to Mauna Loa. Responses of concentrations of both N_2O and SF_6 at Danum Valley, consistent with the annual global wind patterns provide an indication for global transport of N2O and SF6 from the northern hemisphere to Northeast Borneo. Therefore, the relative proximity of East Asia allows for a conjecture that there is a net transportation of anthropogenic GHG from this region to Borneo. Nevertheless, this conjecture needs to be further investigated.

9. Past Temperature Trends

As a country located near the equator and surrounded by oceans, Malaysia experiences almost constant temperatures throughout the year. The daytime is usually hot, and the nighttime is slightly cold. Extremely high temperatures were not found in the tropical maritime landmass[16]. The mean daily temperature in most places is between 26 °C and 28 °C. The annual daily mean temperature difference is less than 2 °C except for east coast of the peninsula, which is affected by cold surges from Siberia during the northeast monsoon. However, there are obvious temperature changes during certain monsoons. During April, when the sun is near Malaysia, the mean daily temperature is the highest. While in December and January, which is during the rainy season over the east coast of the Peninsular Malaysia, the mean daily temperature is the lowest over the region. Similarly, in January and February, which is the rainy season over Sarawak, the mean daily temperature is the lowest over the region[16]. Based on surface temperature observations from existing meteorological stations, Malaysia is facing a significant warming trend[17,18]. The mean rate of increased mean temperatures during 30 years in Malaysia, as shown in Figure 13 were 0.1 °C to 0.6 °C, depending on the location of the stations.

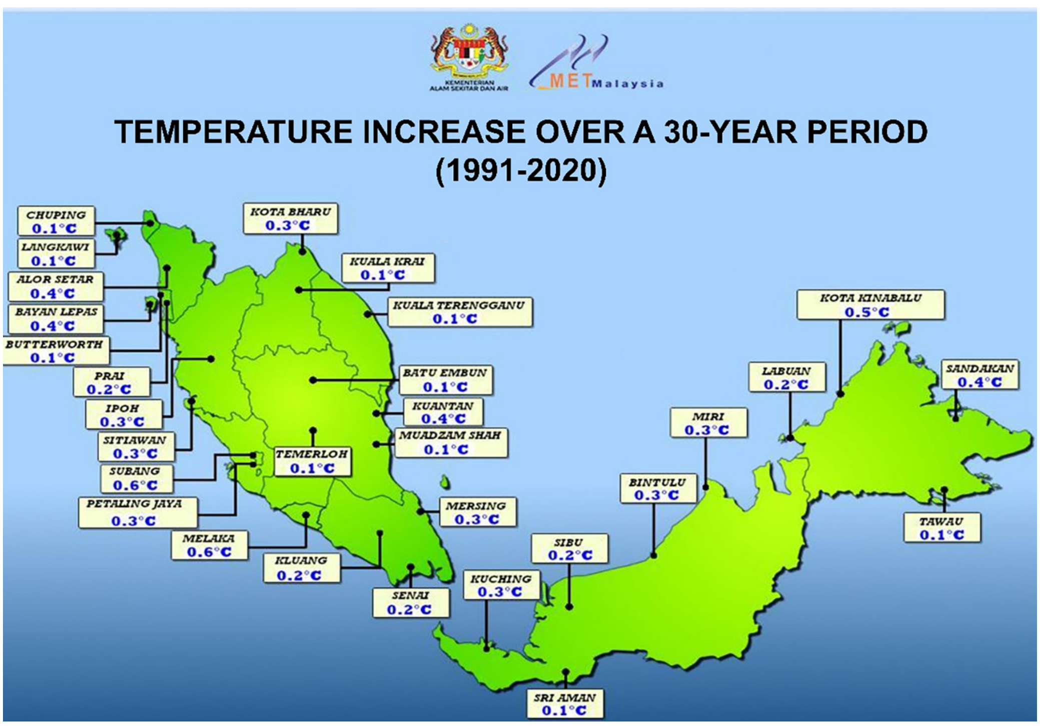


Figure 13: The daily average temperature trend in 30 years.

16 Jamaluddin, AF., Tangang, F., Wan Ibadullah, WM. et al. (2019). Climatology of diurnal rainfall and land-sea breeze in Peninsular Malaysia. *Sains Malaysiana* 48(3): 509-522.

17 Cinco, T.A., Guzman, R.G., Hilario, F.D. & Wilson, D.M. (2014). Long-term trends and extremes in observed daily precipitation and near surface air temperature in the Philippines for the period 1951–2010. *Atmospheric Research* 145-146: 12-26.

18 Supari, Tangang, F., Juneng, L. & Aldrian, E. (2017). Observed changes in extreme temperature and precipitation over Indonesia. International Journal of Climatology 37: 1979-1997.

10. Past Rainfall Patterns

The National Hydrology Research Institute of Malaysia (NAHRIM) conducted a 40-years rainfall pattern study which observed rainfall from the year 1967 to 2017, as shown in Figure 14. The increments of mean yearly rainfall in Sabah & Sarawak over the study periods recorded was higher than those in Peninsular Malaysia. The mean yearly rainfall for Peninsular Malaysia over the historical 40 years was about 2,400 mm. From a spatial distribution perspective, the whole of the east coast of Peninsular Malaysia showed a high yearly rainfall of more than 2,500 mm especially in Terengganu. Other high rainfall areas over the 40-yr analysis period included some areas in the northern and southern Perak, the north-east part of Johor, Kuala Lumpur, and in the inland areas of Selangor. On the other hand, drier areas were found in parts of north-west Johor, the central part of Pahang, the eastern part of Negeri Sembilan and Melaka, the north-west part of the coastal areas in Selangor (extended to the southern coastal area of Perak), northern Kedah, and Perlis wherein, yearly rainfall as low as 1,600 mm were recorded throughout the 40-yr analysis period. However, in general the spatial distribution of rainfall was rather quite consistent throughout the 40-yr analysis period in Peninsular Malaysia.

In Sabah & Sarawak region, the mean yearly rainfall over the past 40 years was about 3,200 mm. In Sabah, the west coast and the north-east region held the highest mean yearly rainfall record of 2,800 mm to 3,100 mm over the 40-yr analysis period. In general, the whole of Sabah had moderate yearly rainfall of 2,200-2,800 mm over the 40-yr analysis period, except for the central region where yearly rainfall was as low as 1,600 mm. In Sarawak, the central and eastern regions received the highest mean yearly rainfall, where the central parts of these two regions even achieved 4,300 mm of yearly rainfall. Other high rainfall regions included the western region of Sarawak and the Limbang area. On average, Sarawak experiences the highest annual rainfall in the country, reaching nearly 4,000 mm per year.

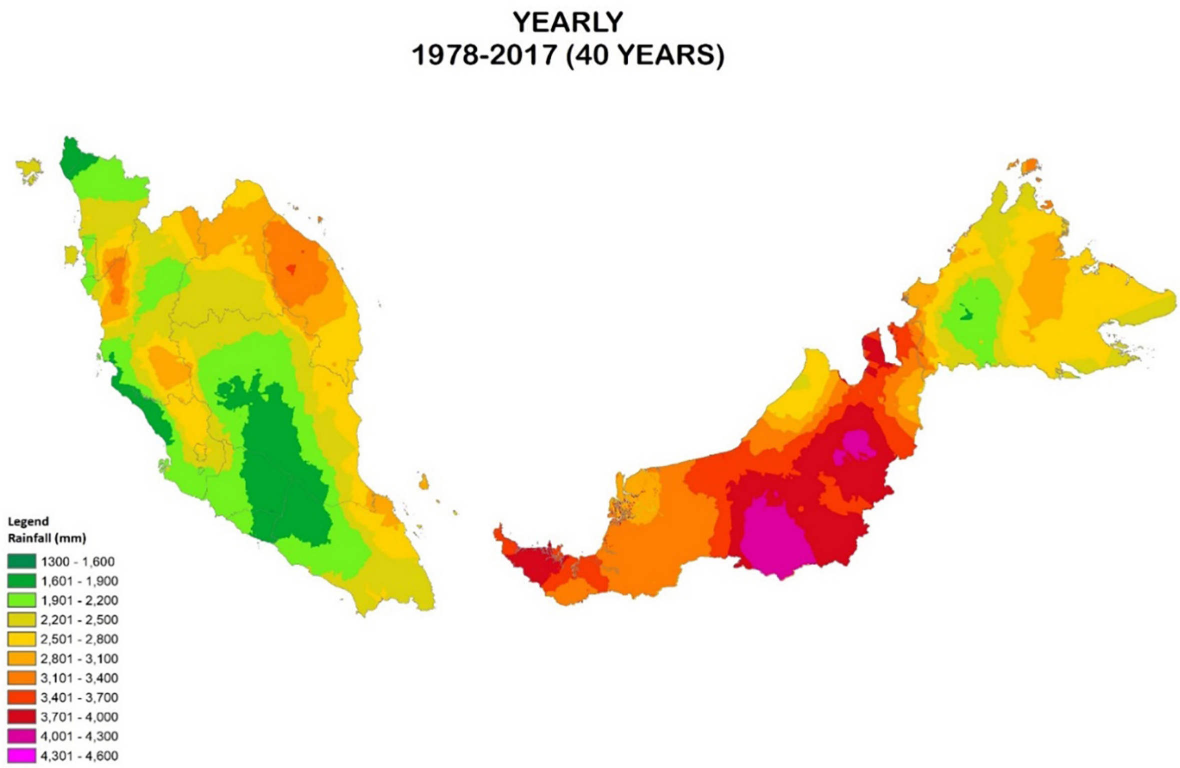


Figure 14: Spatial distribution of 40-year mean yearly rainfall in Malaysia.

11. Observed Sea Level Rise

Global mean sea level (GMSL) has risen by approximately 0.2 [0.15 to 0.25] meters since the pre-industrial era (Fox-Kemper et al. 2021). The mean rate of sea level rise was 1.3 [0.6 to 2.1] mm yr–1 between 1901 and 1971, increased to 1.9 [0.8 to 2.9] mm yr–1 between 1971 and 2006, and further increased to 3.7 [3.2 to 4.2] mm year–1 between 2006 and 2018. Human influence was very likely increasing the surface temperature since at least 1971, and the rate were expected to accelerate in the future, due to the ocean warming and the melting of glaciers associated with the ice sheets. The main acceleration is primarily due to the thermal expansion of seawater, melting of glaciers and ice caps. Given its potential catastrophic and adverse impact on coastal communities around the world, understanding the patterns and drivers of SLR is critical for adaptation and mitigation planning. Historical sea level data provides essential information for this purpose, allowing for the identification of trends and variations in sea level over time.

SLR induces temporary or permanent changes at the coast due to flooding or inundation of low-lying coastal land and/or erosion of shorelines and salinisation of coastal aquifers. The physical vulnerability of the coastline to SLR impacts may combine with an additional influence to generate significant coastal impacts. These findings are discussed in Seneviratne et al. (2012)[19] below:

- Severe storm events that cause storm surges and large wind-driven waves, which can lead to erosion events,
- Changes in sediment supply to the coast due to interventions such as dams,
- Changes in wave magnitude and speed due to sea-level rise, which alters wave refraction and wave direction, which can cause realignment of shorelines,
- Changes in coastal height due to sediment compaction from the removal of oil, gas, and groundwater, and
- The loss of natural protective structures such as coral reefs[20,21] due to increased ocean temperatures[22] and ocean acidification[23].

The sea levels in the Malaysia region are strongly influenced by seasonal and interannual variability due to anthropogenic climate change. Recently, the longer tide gauge and satellite altimetry observations are now available to better understand these variability and trends in sea level deviation.

11.1 Tide gauge and satellite altimeter data

Observations of the sea level of a location or region were recorded from available tide gauge and satellite altimetry datasets by using monthly merged TOPEX/Poseidon and Jason altimetry data on a 1°×1° grid from the period 1993 to 2016 were provided by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The tide gauge provides direct sea level measurement, while satellite altimetry provides data on sea surface heights globally since its launch in 1993. The concept of satellite altimetry is to determine the absolute sea level measured from space through a range of periodic time of reflected radar signal process[24].

[19] Seneviratne, S., Nicholls, N., Easterling, D., Goodess, C., Kanae, S., Kossin, J. et al. (2012). Changes in climate extremes and their impacts on the iatural physical environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge: Cambridge University Press.

[20] Sheppard, C., D.J. Dixon, M. Gourlay, A. Sheppard & R. Payet, (2005). Coral mortality increases wave energy reaching shores protected by reef flats: Examples from the Seychelles. *Estuarine Coastal and Shelf Science* 64(2-3): 223-234.

[21] Gravelle, G. & Mimura, N. (2008). Vulnerability assessment of sea level rise in Viti Levu, Fiji Islands. *Sustainability Science* 3(2): 171-180.

[22] Hoegh-Guldberg, O. (1999) Climate change, coral bleaching and the future of the world's coral reefs. *Marine and Freshwater Research* 50(8): 839-866.

[23] Bongaerts, P., Ridgway, T., Sampayo, E. & Hoegh-Guldberg, O. (2010). Assessing the 'deep reef refugia' hypothesis: Focus on Caribbean Reefs. *Coral Reefs* 29(2): 309-327.

[24] Adebisi, N., Balogun, A-L., Min, T.H. & Tella, A. (2021). Advances in estimating sea level rise: A review of tide gauge, satellite altimetry and spatial data science approaches. *Ocean & Coastal Management* 208.

The tide gauges at Malaysia's coastline were obtained from Permanent Service for Mean Sea Level (PSMSL). Monthly data from 21 stations along Malaysia's coastlines with 4 additional Singaporean stations (Raffles Light House, Sembawang, Sultan Shoal and Tanjong Pagar) are first processed to remove the annual and semi-annual cycles. The distribution of the stations is shown in Figure 15 and their details are presented in Table 1. The stations are categorised based on their regions, which are the West Coast of Peninsular Malaysia (WPM), East Coast of Peninsular Malaysia (EPM) and East Malaysia (EM). On the WPM, the stations are Geting, Cendering, Tanjung Gelang, Pulau Tioman, Tanjung Sedili and Johor Bahru. While the EPM stations are Pulau Langkawi, Pulau Pinang, Lumut, Pelabuhan Kelang, Tanjung Keling dan Kukup. The stations located at EM are Sejingkat, Bintulu, Miri, Labuan, Kota Kinabalu, Kudat, Sandakan, Lahat Datu, and Tawau. The period of data obtained from PSMSL is from 1993 to the latest available data provided by the stations.

Comparisons between the satellite and tide gauge data in Figure 15 are found to agree reasonably well over the historical period for all stations except for Miri and Sejingkat. Comparisons between the Miri tide gauge and neighbouring satellite altimeter reveals that the baseline shift is of the order of 108 mm between 1998 and 2007 (Figure 16). Meanwhile, Sejingkat station has a large negative trend based on tide gauge observations over 1997-2010, which may be partly related to the sensitivity of trend analysis over the short period (just over one decade), possibly also influenced by ENSO-like low-frequency climate variability[25]. This particular tide station was also reported to be affected by increased sedimentation.

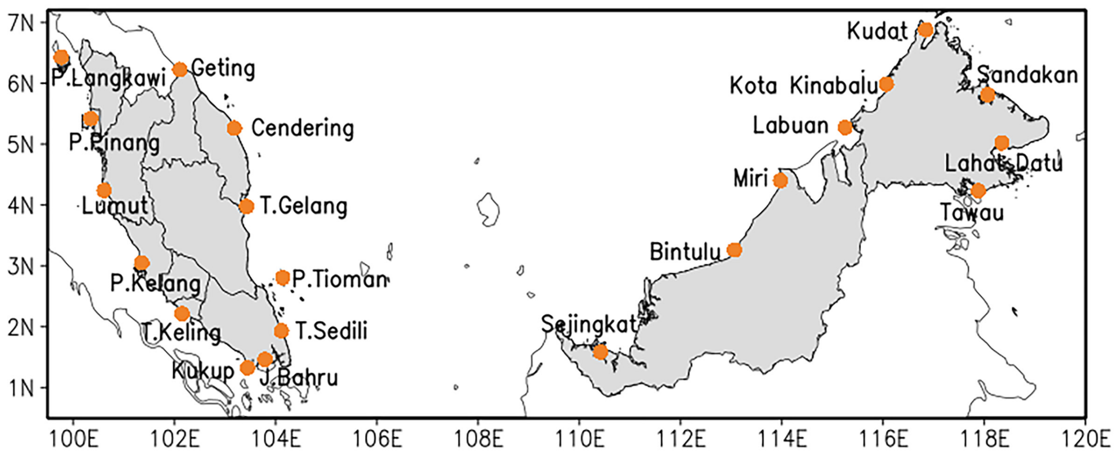


Figure 15: Distribution of tide gauge stations in Malaysia. Source: NAHRIM (2019)[26].

Table 1. The data gap with the period of data for tide gauge stations across the coastline of Malaysia.

Tide Gauge Stations		Coordinate (Latitude °N, Longitude °E)	Period of Data	Tide Gauge (mm/year)	Altimetry (mm/year)
West Coast of Peninsular Malaysia	Pulau Langkawi	6.431, 99.764	Jan 1993-Dec 2018	4.3 [2.1 - 6.6]	3.3 [1.8 - 4.9]
	Pulau Pinang	5.422, 100.347	Jan 1993-Dec 2018	4.7 [2.4 – 7.0]	4.7 [3.2 - 6.2]
	Lumut	4.240, 100.613	Jan 1993-Dec 2018	3.7 [1.8 – 5.7]	4.9 [3.3 - 6.4]
	Pelabuhan Kelang	3.050, 101.358	Jan 1993-Dec 2018	3.2 [0.8 – 5.7]	4.1 [2.2 - 6.0]
	Tanjung Keling	2.215, 102.153	Jan 1993-Dec 2018	3.3 [1.3 – 5.3]	4.8 [3.5 - 6.1]
	Kukup	1.325, 103.443	Jan 1993-Dec 2018	5.9 [4.0 – 7.7]	3.4 [2.3 - 4.4]

25 Lyu, K., Zhang, X., Church, J. A., Hu, J., & Yu, J. (2017). Distinguishing the quasi-decadal and multidecadal sea level and climate variations in the pacific: implications for the ENSO-Like low-frequency variability. *Journal of Climate* 30(13): 5097-5117.

26 National Water Research Institute of Malaysia (NAHRIM). (2019). Available at: https://www.nahrim.gov.my/wp content/up-loads/ CSIRO_Malaysia_SeaLevelRiseReport_FinalReport_2017.pdf. Accessed on: 17 September 2021.

Tide Gauge Stations		Coordinate (Latitude °N, Longitude °E)	Period of Data	Tide Gauge (mm/year)	Altimetry (mm/year)
East Coast of Peninsular Malaysia	Johor Bahru	1.462, 103.792	Jan 1993-Apr 2014	4.4 [2.6 – 6.1]	3.7 [2.6 - 4.8]
	Tanjung Sedili	1.932, 104.115	Jan 1993-Dec 2018	2.5 [1.1 – 3.9]	4.4 [3.5 - 5.4]
	Pulau Tioman	2.807, 104.140	Jan 1993-Oct 2018	4.0 [2.7 – 5.2]	4.4 [3.5 - 5.4]
	Tanjung Gelang	3.975, 103.430	Jan 1993-Dec 2018	4.1 [2.8 – 5.4]	4.3 [3.3 - 5.3]
	Cendering	5.265, 103.187	Jan 1993-Dec 2018	4.1 [2.8 – 5.4]	4.3 [3.3 - 5.3]
	Geting	6.226, 102.107	Jan 1993-Oct 2017	3.6 [1.9 – 5.4]	4.2 [3.0 - 5.3]
East Malaysia	Miri	4.401, 113.974	Jan 1993-Nov 2015	10.0 [8.2 – 12.2]	4.7 [3.4 - 6.0]
	Bintulu	3.262, 113.064	Jan 1993-Dec 2018	2.4 [0.6 – 4.1]	4.5 [3.3 - 5.7]
	Sejingkat	1.583, 110.422	Jan 1997-May 2010	-4.4 [-10.2 – 1.4]	4.9 [3.8 - 6.0]
	Labuan	5.273, 115.250	Jan 1996-Dec 2018	3.0 [0.3 – 5.7]	4.7 [3.2 - 6.2]
	Kota Kinabalu	5.983, 116.067	Jan 1993-Dec 2018	4.4 [2.3 – 6.4]	4.9 [3.3 - 6.4]
	Kudat	6.879, 116.844	Jan 1996-Oct 2018	3.1 [0.4 – 5.8]	5.0 [3.4 - 6.6]
	Sandakan	5.810, 118.067	Sep 1993-Nov 2018	4.1 [1.6 – 6.6]	5.0 [3.1 - 6.9]
	Lahat Datu	5.019, 118.346	Jan 1996-Dec 2018	3.0 [-0.5 – 6.6]	5.6 [3.0 - 8.1]
	Tawau	4.233, 117.883	Jan 1993-Dec 2018	3.8 [1.0 – 6.6]	5.1 [2.7 - 7.5]

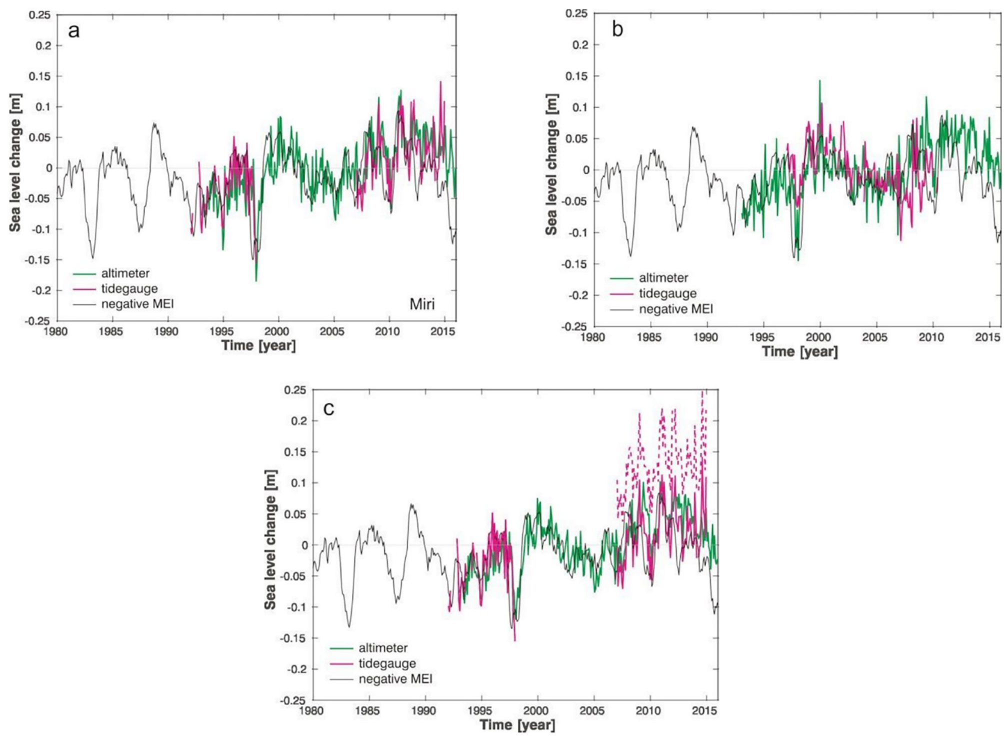


Figure 16: Historical tide gauge (magenta) and altimeter (green) sea level anomalies (metre) for both (a) Miri and (b) Sejingkat stations showing anomalous sea level behaviour as reflected by the 1993-2015 trends. The uncorrected Miri tide gauge record (dashed magenta line) displays a baseline shift of ~108 mm between 1998 and 2007 and can be adjusted (c) using the neighbouring altimeter data. Sejingkat displays an anomalous downward trend over 1997-2010, which is not reflected in neighbouring stations or in the closest altimeter records. Negative Multivariate ENSO Index (MEI) is also plotted in all panels.
Source: NAHRIM (2019)[26].

11.2 Comparison between tide gauge and altimeter observations

In general, the satellite altimetry and tide gauge sea level anomalies agree well over the historical period for all 21 Malaysian and 4 additional Singaporean stations. The inter-annual variability in both records is mainly driven by two modes of climate variability (ENSO and IOD) in the Indo-Pacific.

Trend maps featuring both the altimeter and tide gauge data sets are produced for the entire Malaysian coastline and their immediate adjacent seas (Figure 17). In Table 1, sea level trends computed over the 1993 to 2015 period for all available tide gauge records are given in column 3, satellite records at the closest altimeter grid points for overlapping data records (i.e. when the associated tide gauges have valid data) are given in column 4, and column 5 gives the altimeter trends over the full duration of the records, 1993-2015.

The sea level trends derived from tide gauges and nearby altimetry observations agree with each other within specified uncertainty ranges, except for three locations. At Kukup and Miri, the trends are of similar magnitude, but the rates do not agree within uncertainty ranges, which may be the result of the altimeter point and the tide gauge site being separated by substantial distances or potential local vertical land motions (GPS data could be used to check this latter possibility), or an underestimation of the uncertainty of the calculated trends. For the Sejingkat record (this tide gauge site has been subsequently relocated), the tide gauge indicates a sea level drop at the rate of -4.3 mm/yr over the shorter period 1997-2010, while altimetry indicates a rise at the rate of 3.9 mm/yr over the full altimetry period 1993-2015.

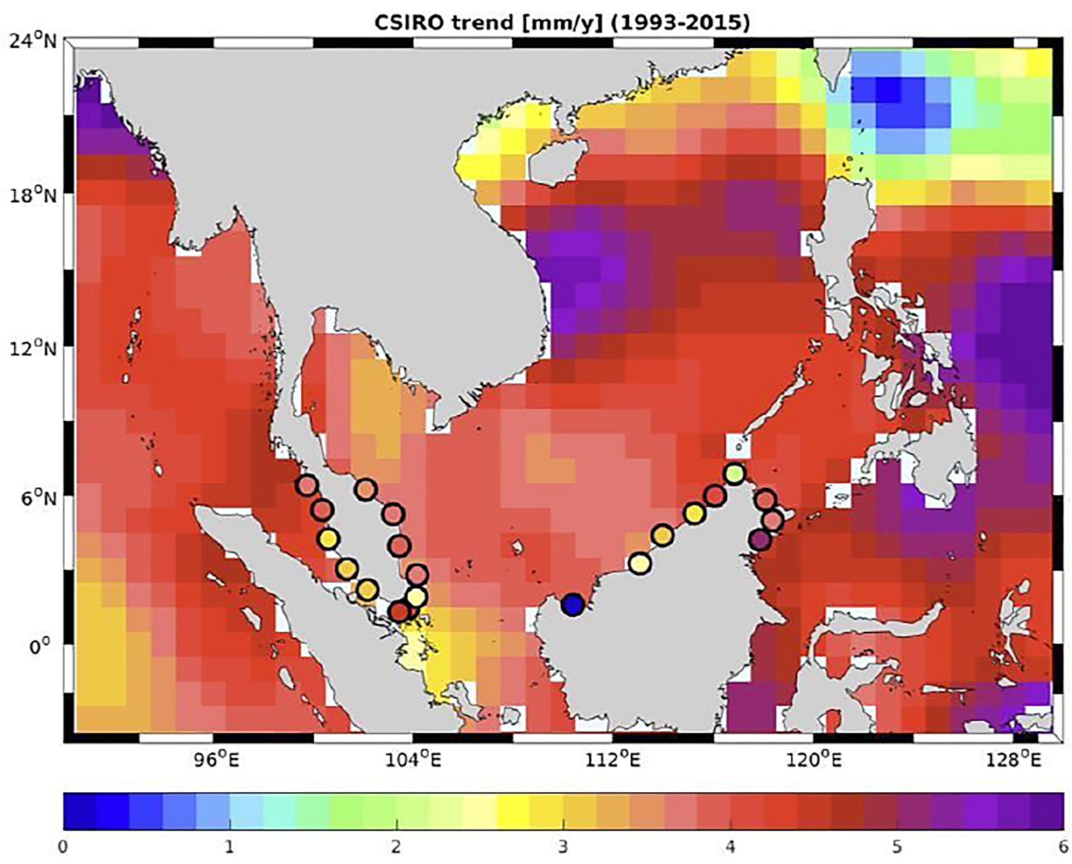


Figure 17: Sea level trends from 1993 to 2015 from CSIRO gridded satellite altimeter (shading) and tide gauges (coloured dots). The CSIRO gridded altimeter product has not been corrected for either inverse barometric effect or glacial isostatic adjustment (GIA).

12. Historical Climate/ Extreme Weather Events

Table 2. Meteorological data collected throughout Malaysia.

	CRITERIA	EXTREME RECORDS	LOCATION
Temperature	Highest temperature recorded	40.1°C	Chuping, Perlis on 9/4/1998
	Lowest temperature recorded	15.7°C	Kuala Krai, Kelantan on 3/2/2014
	Lowest temperature in highland station	10.0°C	Cameron Highlands, Pahang on 1/2/1989
	Lowest temperature variation in a day	0.3°C	Kuantan, Pahang on 25/12/2012
	Greatest temperature variation in a day	19.1°C	Chuping, Perlis on 4/2/2014
Precipitation	Highest rainfall in an hour	164.6 mm	Perai, Pulau Pinang on 14/8/2017
	Highest rainfall in a day (mid-mid)	698.7 mm	Kota Bharu, Kelantan on 2/12/1981
	Highest rainfall in a day (08-08)	608.1 mm	Kota Bharu, Kelantan on 6/1/1967
	Highest rainfall in a year	6078.52 mm	Mulu, Sarawak in 2017
	Lowest rainfall in a year	1151.0 mm	Tawau, Sabah in 1997
	Highest average number of rain day per year	264 days	Mulu, Sarawak in 2021
Wind	Highest mean daily wind speed	11.1 m/s	Mersing, Johor on 3/3/1986
	Highest maximum wind speed	41.7 m/s	Kuching, Sarawak on 15/9/1992
Lightning	Highest number of days with lightning in a year	362 days	Subang, Selangor in 1987
Thunderstorm	Highest number of days with thunderstorms in a year	269 days	Subang, Selangor in 1969

*The analysis is based on records of 42 main meteorological stations until 31 December 2023. Information is based on data observed at lowland stations unless otherwise stated. Cameron Highlands and Ranau stations are categorised as highland stations[27].

12.1 Flood (monsoon & flash flood)

The Federal Territory of Kuala Lumpur and Selangor are at higher risk for flash floods, especially during the northeast monsoon. Other areas that have rapid development and rising population such as Penang, Johor, Negeri Sembilan and Malacca would face similar problems. Heavy rainfall and inadequate drainage system contribute to the frequent and recurrent flash floods. Flood hotspots which include 5,648 locations in 161 districts have been identified. Some states such as Selangor (Klang, Port Klang, Carey Island), Penang (Seberang Perai), Malacca and Johor (Batu Pahat, Johor Strait and Tebrau Strait) have been identified as areas with high risk for floods during high tide, which is also known as a tidal flood.

12.2 Meteorological drought

Malaysia generally rarely experiences prolonged droughts. However, episodes of the El Nino weather phenomenon that occurred in 1982-1983 and 1997-1998 have caused catastrophic droughts in some parts of Malaysia and water shortages in almost all states, especially over west coast states of Peninsular Malaysia and Sabah.

Prolonged droughts will have an impact on ecosystems and agriculture such as the deaths of flora and fauna, livestock and reduction in agriculture yields, shortage of water supply for domestic and industrial uses, increase in diseases related to dehydration and forest fires. All these effects, if not curbed, will create social and economic imbalances.

[27] Malaysian Meteorological Department (MET). (2023). Available at: https://www.met.gov.my/en/ Accessed from: 20 January 2024.

This El Nino phenomenon has an impact on the surrounding nature such as fire in the forest and peatland. It is expected that the effects of global warming will cause El Nino phenomenon (associated with dry weather) occur more frequently. MET Malaysia will issue an early warning of meteorological drought to all parties involved based on the Cumulative Rainfall Deficit and Standardized Precipitation Index (SPI). SPI is an index of dryness based on rainfall distribution (Table 3).

Table 3. Meteorological drought status monitoring classifications.

METEOROLOGICAL DROUGHT STATUS MONITORING

Warning Stage	EXPLANATION
ALERT	The cumulative rainfall deficit for the most recent 3-month period exceeds 35% of normal, AND the most recent month's SPI Index is less than -1.5 **OR** The cumulative rainfall deficit for the most recent 6-month period exceeds 35% of normal AND the most recent month's SPI index is less than -1.5
WARNING	The cumulative rainfall deficit for the most recent 3 months AND 6 months period also exceeds 35% of normal; AND The most recent 3-month SPI index is less than -1.5 as well as the previous dry stage has also been categorised as WARNING
DANGER	The cumulative rainfall deficit for the most recent 3 months AND 6 months period exceeds 35% of normal; AND The most recent 3-month SPI index is less than -2.0, as well as the previous dry stage, has been categorised as WARNING

12.3 Dry spell

A dry spell refers to a period of time during which there is no precipitation. This term is often used in meteorology and climatology to describe extended intervals without rainfall, which can impact agriculture, water supply, and ecosystems. MET Malaysia issues a daily notice of no rain days for more than seven (7) days to relevant agencies such as the Department of Environment, Ministry of Health, Fire and Rescue Department and others for fire management and environmental health (Table 4).

Table 4. Record of dry spells from the 1950s to 2020.

Station	Data Duration	Number of Days	Date
Alor Setar	Jan 1951 - Dec 2020	77	7th Dec 1979 - 21st Feb 1980
P. Langkawi	Jul 1987 - Dec 2020	77	12th Dec 2004 - 26th Feb 2005
Chuping	Jan 1979 - Dec 2020	75	7th Dec 1979 - 19th Feb 1980
Melaka	Jan 1951 - Dec 2020	67	7th Jan 2014 - 14th March 2014
Kluang	Jan 1974 - Dec 2020	65	10th Jan 2014 - 15th March 2014
K. Kinabalu	Apr 1951 - Dec 2020	60	12th Feb 1998 - 12th Apr 1998
K. Krai	Dec 1984 - Dec 2020	59	15th Jan 2014 - 14th March 2014
Prai	Jun 1983 - Dec 2020	59	15th Jan 2014 - 14th March 2014
Kudat	Oct 1981 - Dec 2020	56	8th March 1983 - 2nd May 1983
Labuan	Jun 1951 - Dec 2020	55	22nd Feb 1998 - 2nd May 1998
K. Terengganu	Jan 1985 - Dec 2020	47	6th Feb 2015 - 24th March 2015

Station	Data Duration	Number of Days	Date
Sandakan	Jan 1951 - Dec 2020	46	10th March 1983 - 24th Apr 1983
Kuala Pilah	Mar 2012 - Dec 2020	45	29th Jan 2014 - 14th March 2014
K. Bharu	Jan 1951 - Dec 2020	42	3rd Apr 2016 - 14th May 2016
Kuantan	Jan 1951 - Dec 2020	42	19th March 1983 - 29th Apr 1983
Bayan Lepas	Jan 1951 - Dec 2020	41	22nd Dis 1996 - 31st Jan 1997 | 11th Jan 2014 - 20th Feb 2014
Tawau	Jan 1960 - Dec 2020	41	11th March 1983 - 20th Apr 1983
Mersing	Jan 1951 - Dec 2020	40	17th Jan 2005 - 25th Feb 2005
Lubok Merbau	Jan 1993 - Dec 2020	39	12th Jan 2014 - 19th Feb 2014
Batu Pahat	Aug 1992 - Dec 2020	36	11th Jan 2014 - 15th Feb 2014
Butterworth	Jan 1985 - Dec 2020	35	11st Jan 2014 - 14th Feb 2014
Senai	Feb 1974 - Dec 2020	34	9th Feb 2014 - 14th Mac 2014
Sitiawan	Jan 1951 - Dec 2020	34	23rd Jan 2005 - 25th Feb 2005
KLIA	Jul 1998 - Dec 2020	33	14th Jan 2014 - 15th Feb 2014
Gong Kedak	Nov 2006 - Dec 2020	33	16th Apr 2016 - 18th Mei 2016
Muadzam Shah	Aug 1983 - Dec 2020	30	16th Jan 2014 - 14th Feb 2014
Miri	Jan 1951 - Dec 2019	29	5th Feb 2010 - 5th March 2010
Batu Embun	May 1982 - Dec 2020	28	31st Jan 1987 - 27th Feb 1987
Temerloh	Aug 1978 - Dec 2020	27	1st March 2016 - 27th March 2016
Cameron Highlands	Apr 1983 - Dec 2020	26	26th Jan 2002 - 20th Feb 2002
Kerteh	Jan 2015 - Dec 2020	25	28th Feb 2019 - 24th March 2019
Bintulu	Jan 1951 - Dec 2020	24	22nd Jan 1973 - 14th Feb 1973
Keningau	Aug 2009 - Dec 2020	24	26th Feb 2010 - 21st March 2010 | 20th Feb 2014 - 29th June 2014
Ipoh	Jan 1951 - Dec 2020	23	5th Jan 1979 - 27th Jan 1979
Petaling Jaya	Jan 1971 - Dec 2020	22	16th June 1985 - 7th Jul 1985
Subang	Jan 1951 - Dec 2020	22	21st Jan 2014 - 11th Feb 2014
Sibu	Sept 1961 - Dec 2020	20	31st Jul 1981 - 19th Aug 1981
Sri Aman	Jan 1983 - Dec 2020	20	26th Jun 2006 - 15th Jul 2006 | 30th June 2015 - 19th Jul 2015
Kuching	Jan 1951 - Dec 2020	18	1st Jul 1958 - 18th Jul 1958
Mulu	Jan 1951 - Dec 2020	17	13th June 2012 - 29th June 2012
Ranau	June 2012 - Dec 2020	17	20th Feb 2019 - 8th March 2019
Kapit	Feb 2007 - Dec 2020	15	30th Jul 2019 - 13th Aug 2019
Limbang	Jan 2006 - Dec 2020	14	17th March 2015 - 30th March 2015 | 29th Aug 2019 - 11th Sept 2019

a) Heat wave

Heat waves are a period with unusually high temperatures exceeding the daily mean maximum temperature and relatively hot weather conditions (Figure 18). It usually lasts for several days or several weeks. It is defined when the daily maximum temperature exceeds 37 ºC for three consecutive days (Table 5). The heat wave phenomenon usually peaks at the end of the Northeast Monsoon in February to April. It affects mostly the states of Perlis, Kedah, Pulau Pinang and Northern Perak, as well as the inland areas of Kelantan, Terengganu and Pahang.

Table 5. Status, criteria and action plan in heat wave management.

LEVEL	STATUS	CRITERIA	ACTION
Level 0	Normal	The daily maximum temperature is less than 35.0°C.	Continuous monitoring.
Level 1	Alert	Daily maximum temperature 35.0°C to 37.0°C for at least 3 consecutive days.	
Level 2	Heatwave	Daily maximum temperature exceeds 37.0°C to 40.0°C for at least 3 consecutive days.	Announcement of the heat wave by the Ministry of National Resources and Environmental Sustainability (NRES) to allow the relevant authorities to take further action such as school closure etc..
Level 3	Extreme Heatwave	Daily maximum temperature exceeds 40.0°C and above for at least 3 consecutive days.	Notification to NADMA and Prime Minister for the declaration of disaster.

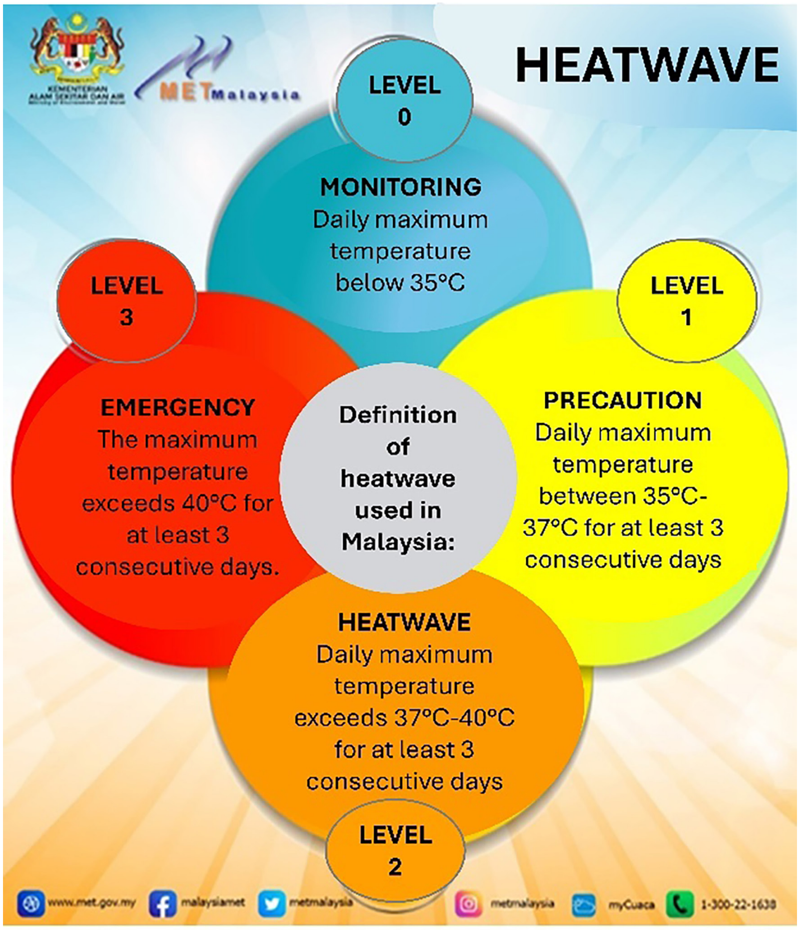


Figure 18: Heatwave definitions used in Malaysia.

12.4 Thunderstorm

a) Thunderstorm trend

In Malaysia, thunderstorms are a frequent occurrence that can happen at any time of the year, especially during late afternoons to late evening. Every thunderstorm generates lightning that poses a threat to human life. Heavy rainfall caused by thunderstorms can lead to flash floods and landslides, while strong winds and hailstones associated with some thunderstorms can also be hazardous.

Based on the observation of 29 Principal Meteorological Stations datasets from 2014 to 2023, on average, 141 days of thunderstorms every year were recorded (Figure 19 and Figure 20). The highest number of days with thunderstorms in a year was Subang with 269 days, recorded in 1969.

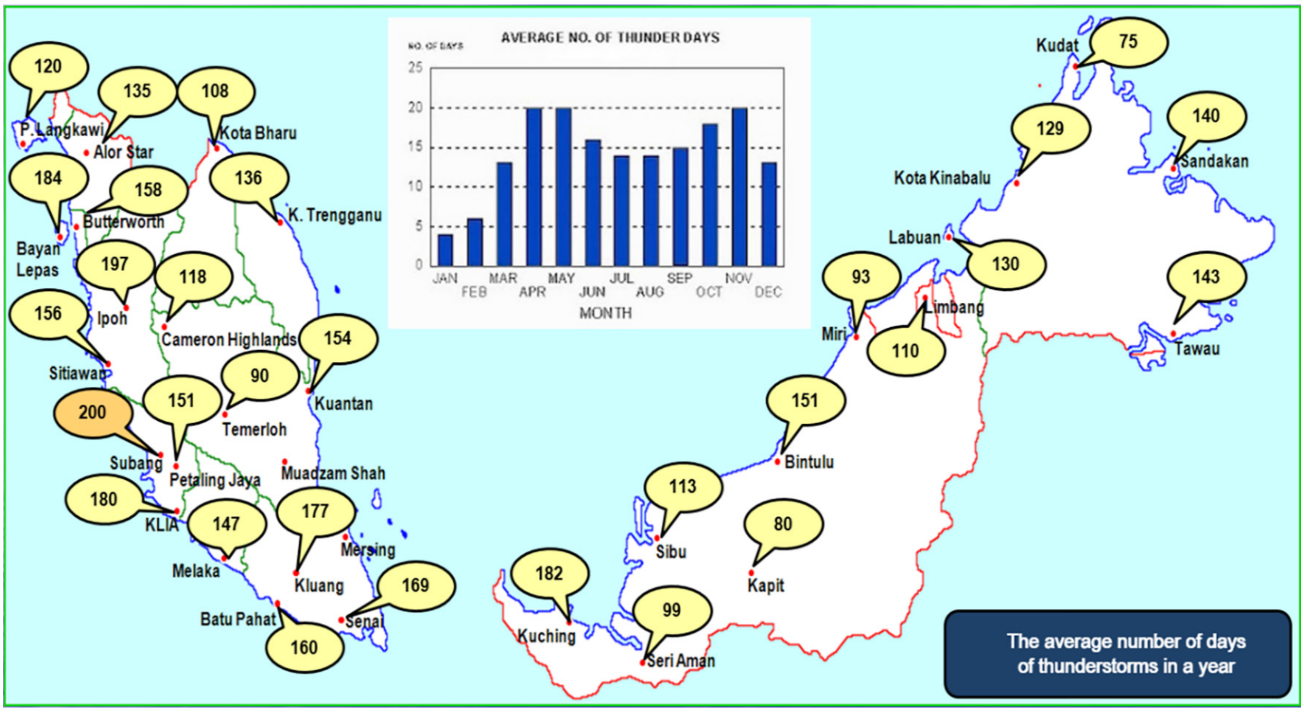


Figure 19: The average number of days of thunderstorms in a year.

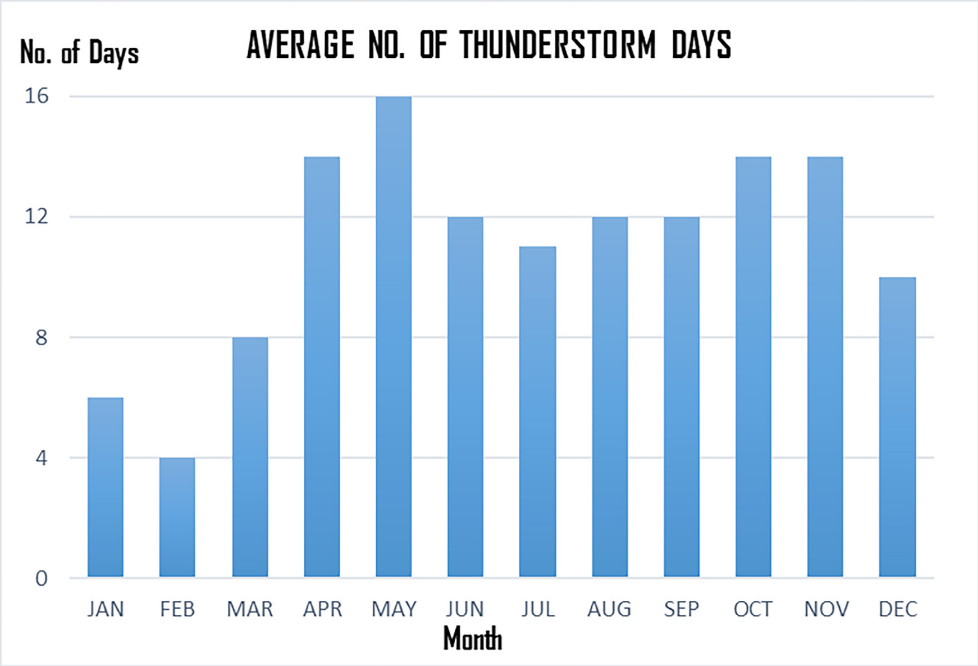


Figure 20: Average no of thunderstorms days dataset 2014-2023.

13. Climate Variability

An understanding of key processes in the climate system of a particular region is of significant importance for assessment of climate change and variability. Climate variability refers to the natural fluctuations in climate conditions over different time periods, ranging from daily, monthly, annually to decades, and significantly influence weather patterns. It includes changes in temperature, precipitation, wind patterns, humidity, and other climatic factors.

Climate variability arises from a combination of internal climate processes such as ocean circulation, atmospheric circulation, interaction between the atmosphere and ocean, as well as external factors such as volcanic eruption and solar variability. Climate variability can be categorised into different timescales, each with its own characteristics and influencing factors, namely diurnal, seasonal, interannual and decadal variability.

Malaysia is geographically located in between two large oceans i.e. the Pacific Ocean to the east and the Indian Ocean to the west, and hence, its climate is also strongly influenced by the natural climate variability associated with these oceans (Figure 21). Knowledge of how these natural climate phenomena modulate climate variability over the region is of central importance to the understanding of climate change impacts in this region[28].

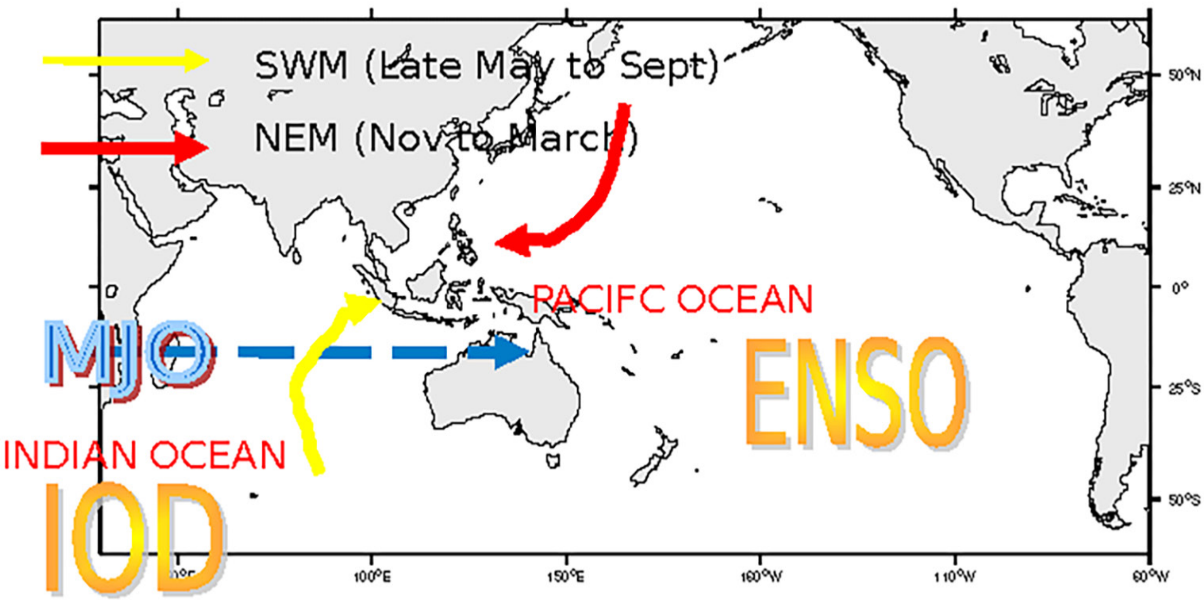


Figure 21: Monsoon and dominant modes of climate variability.

13.1 Short-term variability

Short-Term Climate Variability include diurnal, subseasonal and seasonal variability. Diurnal variability refers to the fluctuations in weather conditions that occur on a daily basis, meanwhile subseasonal variability typically occurs over timescales ranging from a few days to a few weeks. On the other hand, seasonal variability can span froma few months to a year.

a) Diurnal variability

Diurnal forcing is created due to temperature variations across regions as a result of daily variations in solar radiation. These diurnal forcings, combined with the geographical features of the area such as topography, influence the formation of localised wind patterns. Localised wind patterns like sea and land breezes, mountain and valley breezes contribute significant impact to diurnal climate variability.

28 Tangang, F. T., Juneng, L., Salimun, E. et al. (2012). Climate change and variability over Malaysia: gaps in science and research information. *Sains Malaysiana* 41(11): 1355-1366.

Rainfall activities in Malaysia respond to diurnal forcing where convection rainfall usually attains maximum intensity in the evening over land, whilst in a marine area, maximum convective activities generally occur in the morning. Diurnal variations are significant over most seasons especially during the inter-monsoon months of April to May and September to October over the west coast states of the Peninsula. The diurnally forced land-sea breeze that interact with larger scale background wind such as the wet phase of Madden-Julian Oscillation (MJO) can produce intensive convective activities that lead to extreme rainfall over the region. This relationship is crucial in understanding the storm development and extreme weather events in the region.

b) Subseasonal variability

The subseasonal climate variability's most prominent example is Madden-Julian Oscillation (MJO). MJO is a large-scale atmospheric phenomenon characterised by the eastward propagation of areas of enhanced and suppressed convection along the equator in 30 to 60 days, on average. MJO can be categorised into weak and active phases based on the strength and intensity of its convective activity and atmospheric circulation patterns.

During the active phase of MJO over the Maritime Continent, stronger and more organised propagations of enhanced and suppressed convection across the continent. During enhanced phase of MJO, increased cloudiness, precipitation, and thunderstorm activity, leading to heavy rainfall and localised flooding can occur in some regions in Malaysia. In contrast, during suppressed the weak phase of the MJO, suppressed convection across the continent is less pronounced resulting in heatwave and drought in Malaysia. For instance, extended dry spells in 2014 resulted in an increase of non rainfall days over Peninsular Malaysia (as shown in Table 4).

Additional notable impacts of the MJO include modulating the strength of monsoon rains in Malaysia, influencing tropical cyclone activity in the western Pacific Ocean and South China Sea, and indirectly influencing temperature variability in Malaysia. There has been limited work on how MJO would respond to global warming. Jones and Carvalho (2011)[29] suggest a strong influence of anthropogenic warming on MJO frequencies, they showed that the number of MJO events per year is projected to increase from about 3.9 in 1948-2008 to about 5.7 for 2049-2099. The probability of very active years (5 or more events) is projected to significantly increase from 0.51 ± 0.01 (1990-2008) to 0.75 ± 0.01 (2010-2027) and 0.92 ± 0.01 (2094-2099). This study suggests that by the end of the 21st century, any year would almost certainly be classified as an 'MJO-active year' with 5 or more events in each year[27]. The increasing number of MJO occurrences in the future would have major implications on rainfall variability over Malaysia[30].

c) Seasonal variability

In Malaysia, seasonal variability comprises of Northeast Monsoon (November to March), Inter-monsoon (April to May, September to October) and Southwest Monsoon (May to September). Northeast Monsoon usually occurs in early November and ends in March with steady easterly or northeasterly winds of 10 to 20 knots. Occasionally, during this period, strong pulses of wind known as a cold surge penetrates to the most southern region of the South China Sea[45]. During this period, continuous heavy rainfall episodes are common in the east coast of Malaysia region, leading to potential flooding, landslides, and other weather-related hazards.

The Southwest Monsoon usually begins in the second half of May or early June and ends in September, with south-westerly winds generally prevail below 10 knots. With the

[29] Jones, C. & Carvalho, L. (2011). Stochastic simulations of the Madden-Julian oscillation activity. *Climate Dynamics* 36: 229-246.

[30] Jamaluddin, A.F., Tangang, F. & Juneng, L. (2022). Ayunan Madden-Julian: Pengaruhnya di Malaysia dan Asia Tenggara. Penerbit Universiti Kebangsaan Malaysia. ISBN: 978 629 7547 00 8.

exception of Sabah, most part of Malaysia experience relatively dry weather during the monsoon. However, west coast states of Peninsular experience occasional heavy rainfall in the morning as squall lines develop over the Strait of Malacca. The inter-monsoon seasons typically begin in late March to early May and October to mid-November. The winds are generally light and variable, with afternoon thunderstorms being common over the west coast and inland area of Peninsular Malaysia.

There has been limited work done to understand long term changes of monsoon circulations over the Maritime Continent. Juneng and Tangang (2010)[31] highlighted long-term changes of the Borneo vortex during northeast monsoon over the Maritime Continent. The frequency of the Borneo vortex has increased over the 1962-2007 period. During this period, the centres of the vortex also shifted north-westward, due to the strengthening of easterlies over the southern region of the South China Sea[29]. This location shift has important implications as the interaction between the vortex and the cold surge over warm waters could strengthen the system. The interaction between the vortex and the cold surge enhances the formation of low-pressure systems over the South China Sea, hitting and crossing the Peninsular Malaysia region. On 24 to 27 November 2023, tropical depression Invest 99W occurred over South China Sea and hit Terengganu and Kelantan states, resulting in extreme rainfall in the region. Another example is the formation of tropical depression (TD) 29W on 17 December 2022 over the coastal area of Pahang. The tropical depression crossed over the Peninsular and remained quasi-stationary over the straits of Malacca for a few days. This caused heavy rainfall, with an estimated loss of RM 6.1 billion and more than 60 people losing their lives in the state of Selangor. Others example was the major flood that occurred over Penang Island on 4 November 2017. Heavy rain for 17 hours with strong winds caused thousands of houses flooded, landslides, more than 8000 people were evacuated and 7 people died throughout the state. An event that occurred before in Penang was typhoon Vamei in 2001. In general, there is an increase in severe weather events during the Northeast Monsoon related to the formation of low-pressure systems over the South China Sea that hit and cross the Peninsular Malaysia region.

13.2 Interannual climate variability

Interannual variability refers to climate fluctuations that occur on timescales of one to several years. This type of variability is often associated with natural climate phenomena, such as the El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD).

a) El Niño-southern oscillation (ENSO)

ENSO involves a periodic change in sea surface temperatures and atmospheric circulations in the tropical Pacific Ocean. ENSO has three main phases, namely El Niño, La Niña, and neutral. During El Niño, the sea surface temperatures in the central and eastern Pacific Ocean is warmer than usual, which can cause the land surface temperatures to increase by around 0.5°C to 1.5°C and decreasing of rainfall amount all over the country. El Niño can cause heatwaves to occur and prolong over the north of the Peninsula, north of Perak, inland Pahang and inland Kelantan. A heat wave is a period with daily maximum temperature exceeding 37°C, which usually lasts for several days and sometimes can last for several weeks. Less rainfall during El Niño can also cause a reduction in dam levels in the country (Figure 22).

[31] Juneng, L. & Tangang, F. (2010). Long-term trends of winter monsoon synoptic circulations over the maritime continent: 1962–2007. *Atmospheric Science Letters* 11(3): 199-203.

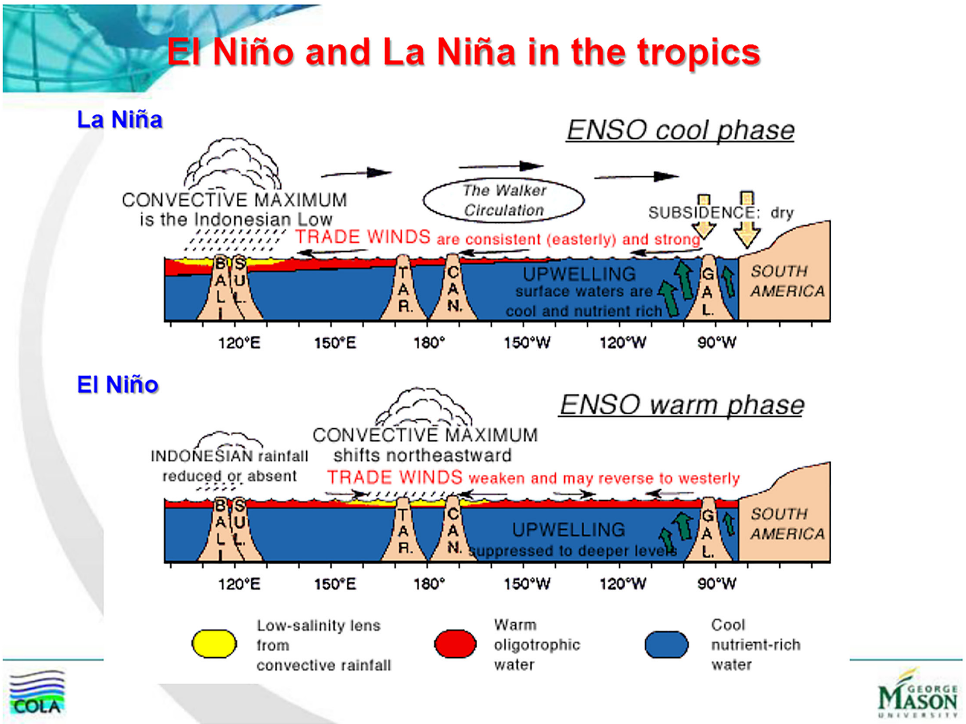


Figure 22: Schematic diagram for El Niño and La Niña.

La Niña events are characterised by cooler-than-average sea surface temperatures (SSTs) in the central and eastern Pacific Ocean. La Niña can increase rainfall in the western Pacific, Southeast Asia, and parts of Australia, which may lead to flooding, landslides, and agricultural disruptions as a result of enhanced trade winds and changes in atmospheric circulation patterns in these regions.

A neutral ENSO state refers to conditions in the tropical Pacific Ocean where sea surface temperatures and atmospheric circulation patterns are near the long-term average. During a neutral ENSO phase, Malaysia may experience normal rainfall patterns, normal temperature range and normal monsoon activity.

Changes in ENSO characteristics would alter how it impacts regional climate change. The assessment provided in the Fourth Assessment Report 4 (AR4) IPCC indicated that there is no consistent discernible change in the projected ENSO amplitude as well as frequency in the 21st century. However, AR4 also suggested that the coupled atmosphere-ocean system in the tropical Pacific tends to prefer the El Nino Modoki mode after the 1980s, due to changes of ocean sub-surface temperature distribution along the equatorial Pacific (Ashok et al. 2007). Climate projections for the 21st century also showed a tendency for the Modoki type of El Nino than the conventional type (Ashok et al. 2007), indicating the probable influence of anthropogenic warming in the El Nino characteristic. An increasing number of Modoki types of El Nino in the 21st century would likely exert more droughts and heat waves over Peninsular Malaysia during the January – April period.

b) Indian Ocean Dipole (IOD)

In addition to ENSO, Malaysian climate variability is also modulated by the Indian ocean modes of variability. The IOD is a manifestation of the Bjerknes mechanism associated with the coupled atmosphere-ocean system of the Indian ocean[32]. It can occur in conjunction with El Niño or independently. A positive mode of IOD is characterised by

[32] Saji, N.H., Goswami, B.N., Vinayachandran, P.N. & Yamagata, T. (1999). A dipole mode in the tropical Indian Ocean. *Nature* 401: 360-363.

a warm SST in the south, while negative mode is by a cool SST in the western tropical basin of the Indian ocean[30]. The evolution of an EL Nino event usually takes about a year, an IOD only lasts for about 5 to 6 months, usually from July to November. The IOD affects rainfall over the Maritime Continent, the Indian subcontinent, Australia and eastern Africa.

During a positive mode of IOD, sea surface temperatures are cooler than average in the western Indian Ocean and warmer than average in the eastern Indian Ocean. This temperature gradient leads to changes in atmospheric circulation patterns, which can influence weather and climate conditions in surrounding regions. A positive mode of IOD leads to an increase in rainfall in parts of East Africa, India, and Southeast Asia, as well as drier conditions in Australia, Indonesia and Malaysia.

Conversely, during a negative mode of IOD, sea surface temperatures are warmer than average in the western Indian Ocean and cooler than average in the eastern Indian Ocean. This reversal of temperature anomalies may result in decreased rainfall in parts of East Africa and India, along with wetter conditions in Australia, Indonesia and Malaysia.

IOD variability has become more visible since the 1970s. However, global warming climate simulation results do not seem to indicate that the IOD is strengthening[33]. Nevertheless, the asymmetry of the IOD pattern that indicates a stronger cold structure on the eastern side and a weaker warm structure on the western side could be associated with anthropogenic warming[34]. Such dominant 'cold' patterns in the eastern side may have an impact on regional climates over the Maritime Continent. Generally, large knowledge gaps still exist in terms of how anthropogenic warming in the Indian ocean would affect extreme events such as flood and droughts over Malaysia.

14. Projected Climate in Malaysia

NAHRIM, as a national focal point and proactive water research institute engaged in research, development, and commercialisation of innovation (RDCI) activities related to climate change, is presently in the process of updating its climate model to align with the latest advancements outlined in IPCC AR6. While this initiative is underway, the hydro-climate projection dataset was derived from the preceding climate model version, AR5, continues to be employed for evaluating impact, vulnerability, and adaptation in Malaysia. Key parameters frequently utilised in this analysis encompass projected air temperature, projected rainfall, sea level rise and others.

14.1 Projected air temperature

Projected average annual air temperatures for the periods of early-century, mid-century and late-century for the hydrological regions of the country, is shown in Figure 23. The average annual air temperatures for the whole country showed an increasing trend and could increase by 0.5-0.8 ^{o}C in early-century (2010-2039), 1.1-1.5 ^{o}C by mid-century (2040-2069), and 1.7-2.1 ^{o}C by late-century (2070-2099). Among the regions, Region SW-1 in Sarawak was estimated to have the highest increments throughout the century.

33 Ihara, C., Kushnir, Y. & Cane, M.A. (2008). Warming trend of the Indian Ocean SST and Indian Ocean Dipole from 1880 to 2004. *Journal of Climate* 21: 2035-2046.

34 Zheng, X-T., Xie, S-P., Vecchi, G.A., Liu, Q. & Hafner, J. (2010). Indian Ocean Dipole response to global warming: Analysis of ocean-atmospheric feedbacks in a coupled model. *Journal of Climate* 23: 1240-1253.

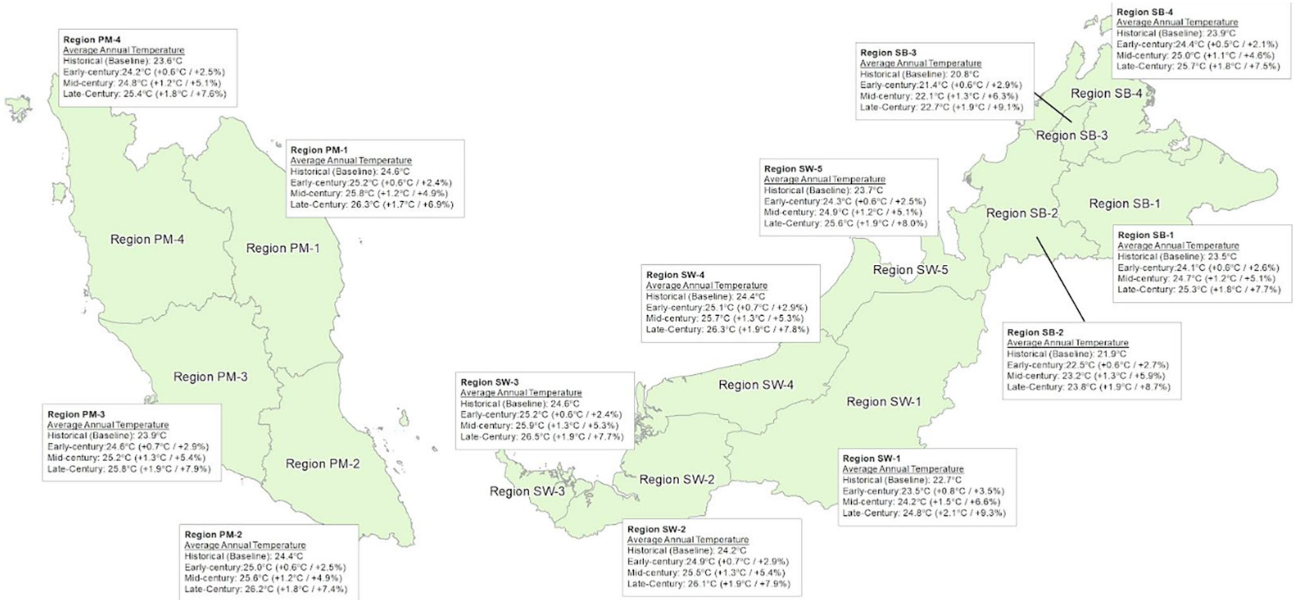


Figure 23: The projected average annual air temperature for the 13 hydrological regions in Malaysia.

14.2 Projected rainfall

As shown in Figure 24, all the hydrological regions in the country are expected to face increments of average annual rainfall throughout the century. Overall, the regions in Sabah and Sarawak showed higher increments during the early-century (6.7-15.2%), mid-century (11.2-19.4%) and late-century (14.8-25.4%) timelines. In Peninsular Malaysia, the increments for early-century, mid-century and late-century were 3.5-8.0%, 7.8-11.9% and 8.9-12.5%, respectively. Among the regions, Region SW-3 in Sarawak may face the highest increments throughout the century. By the late-century, extreme high average annual rainfalls could be expected at Region SW-1 (4,619 mm) and Region SW-3 (4,336 mm) in Sarawak, and Region SB-3 (4,262 mm) in Sabah.

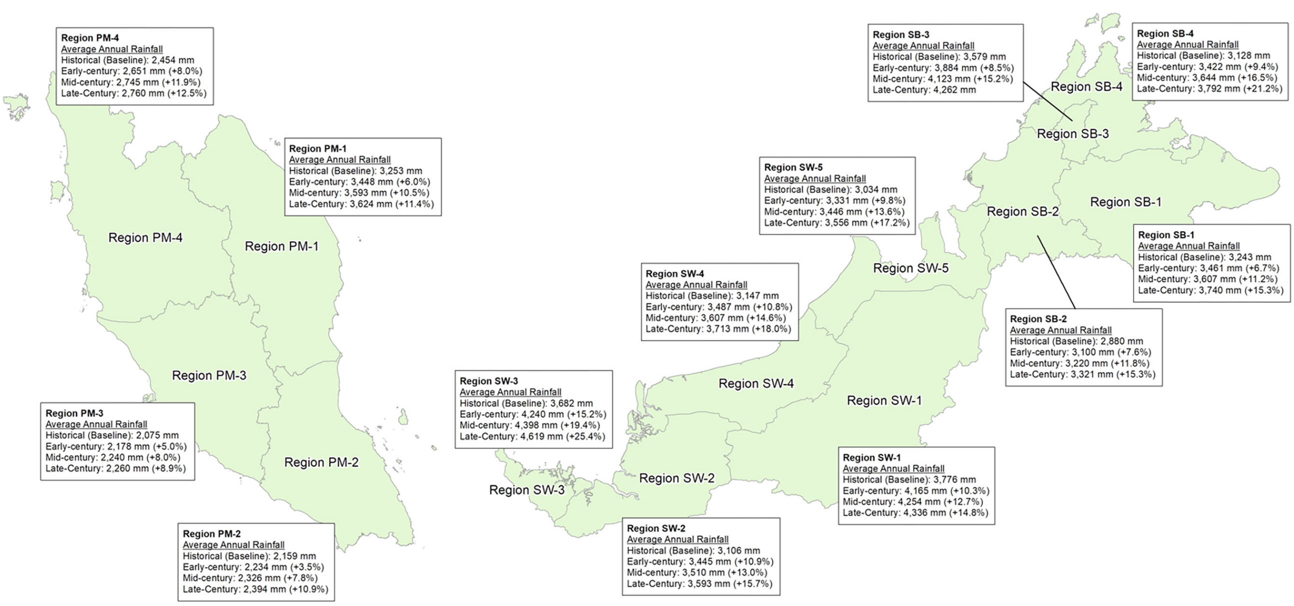


Figure 24: The projected average annual rainfall for the 13 hydrological regions in Malaysia.

14.3 Projected sea level rise

The improved understanding of 20th century sea level rise and the factors leading to the regional differences in the rate of rise has led to the development and usage of techniques for the projection of global mean and regional distribution of sea level rise for the 21st century[35]. As a result, the IPCC provided probabilistic regional projections of sea level rise for the first time in the Fifth Assessment Report (AR5)[36]. The regional projections for Malaysia are based on the methods from Church et al. (2011)[37] and the results from the AR5 projections. Regional projections using the same method have been used for sea level projections for Australia[38] and Vietnam[39].

a) Contribution to sea rise from a global aspect

As discussed in the Impact of Climate Change: Sea Level Rise Projections For Malaysia 2017 by NAHRIM (2019), the AR5 utilized projections of scenarios of Representative Concentration Pathways (RCPs) that range from high concentrations representing continued growth of emissions in a business-as-usual fashion (RCP8.5), to lower concentrations representing very strong mitigation and removal of carbon dioxide from the atmosphere in the second half of the 20th century (RCP 2.6) and two intermediate scenarios (RCP 4.5 and RCP 6.0; the number is the approximate value of radiative forcing in Watt/m^2 from greenhouse gas increases by 2100). Note that of these four scenarios, only RCP 2.6 is projected to result in warming that is likely (66% probability) to be less than 2°C above preindustrial temperatures.

To estimate future sea level changes, projected changes in ocean density and circulation (obtained directly from available climate models) are combined with additional sea level contributions from the loss of mass from glaciers, the surface mass balance and the dynamic response of the Greenland and Antarctic ice sheets and changes in land-water storage as evaluated in the IPCC AR5[34]. How these contributions and associated uncertainties are combined to form global mean sea levels can be found in the supplementary materials of Chapter 13 of the IPCC Fifth Assessment Report[34]. In total, sea level data from 28 Coupled Model Intercomparison Project (CMIP5) models using RCPs 4.5 and 8.5, 21 models using RCP 2.6, and 16 models using RCP 6.0 were available for developing the projections. All CMIP5 models used are listed in Table 6.

The contributions to global mean sea level change for the four RCPs are given in Figure 25. The projected global mean SLR by 2100 relative to 1986–2005 varies from 28–61 cm for the RCP 2.6 (strong mitigation scenario) to 52–98 cm for the RCP 8.5 (high emissions scenario), where the range for each scenario was estimated to be likely (covering 66% of the probabilities). For RCPs 8.5 and 6.0, the rate of Global Mean Sea Level (GMSL) rise increases throughout the 21st century, whereas for RCP 2.6 and 4.5, the rate of rise decreases after 2030 and 2070, respectively. For both the historical period and projections for the 21st century, the largest contributions to global mean sea level change come from ocean thermal expansion and the loss of mass from glaciers, with growing contributions from the ice sheets, particularly in the second half of the 21st century and beyond.

A larger GMSL could occur prior to 2100 as a result of marine ice sheet instability in West Antarctica[34,40], but there was insufficient scientific evidence at the time of the AR5 to assign a specific likelihood to values larger than the *likely* range defined above. Any additional contribution from the potential collapse of marine-based sectors of the Antarctic Ice Sheet, if initiated, was assessed to not exceed several tenths of a metre of GMSL rise by 2100[34]. Recent observations indicate an increased loss of ice from West Antarctica[38] and recent modelling[41] simulates an increased outflow from the Antarctic Ice Sheet.

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35 Slangen, A.B.A., Katsman, C.A., van de Wal, R.S.W. et al. (2012). Towards regional projections of twenty-first century sea-level change based on IPCC SRES scenarios. *Climate Dynamics* 38: 1191-1209.

36 Church, J.A., Clark, P.U., Cazenave, A., Gregory, J.M., Jevrejeva, S., Levermann, A. et al. (2013). Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

37 Church, J. A. & White, N.J. (2011). Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics 32: 585-602.

38 Mcinnes, K.L., Church, J., Monselesan, D., Hunter, J. R., O'Grady, J.G., Haigh, I. et al. (2015). Information for Australian impact and adaptation planning in response to sea-level rise. *Journal of Southern Hemisphere Earth Systems Science* 65(1): 127-149.

39 Katzfey, J., McGregor, J. & Suppiah, R. (2014). High-resolution climate projections for Vietnam: Technical Report. CSIRO, Australia.

40 Rignot, E., Mouginot, J., Morlighem, M. Seroussi, H. & Scheuchl, B. (2014). Widespread, rapid grounding line retreat of Pine Island, Thwaites, Smith, and Kohler glaciers, West Antarctica, from 1992 to 2011. *Geophysical Research Letters* 41: 3502-3509.

41 Ritz, C., Edwards, T., Durand, G., Payne, A.J., Peyaud, V. & Hindmarsh, R.C.A. (2015). Potential sea-level rise from Antarctic ice-sheet instability constrained by observations. *Nature* 528:115-118.

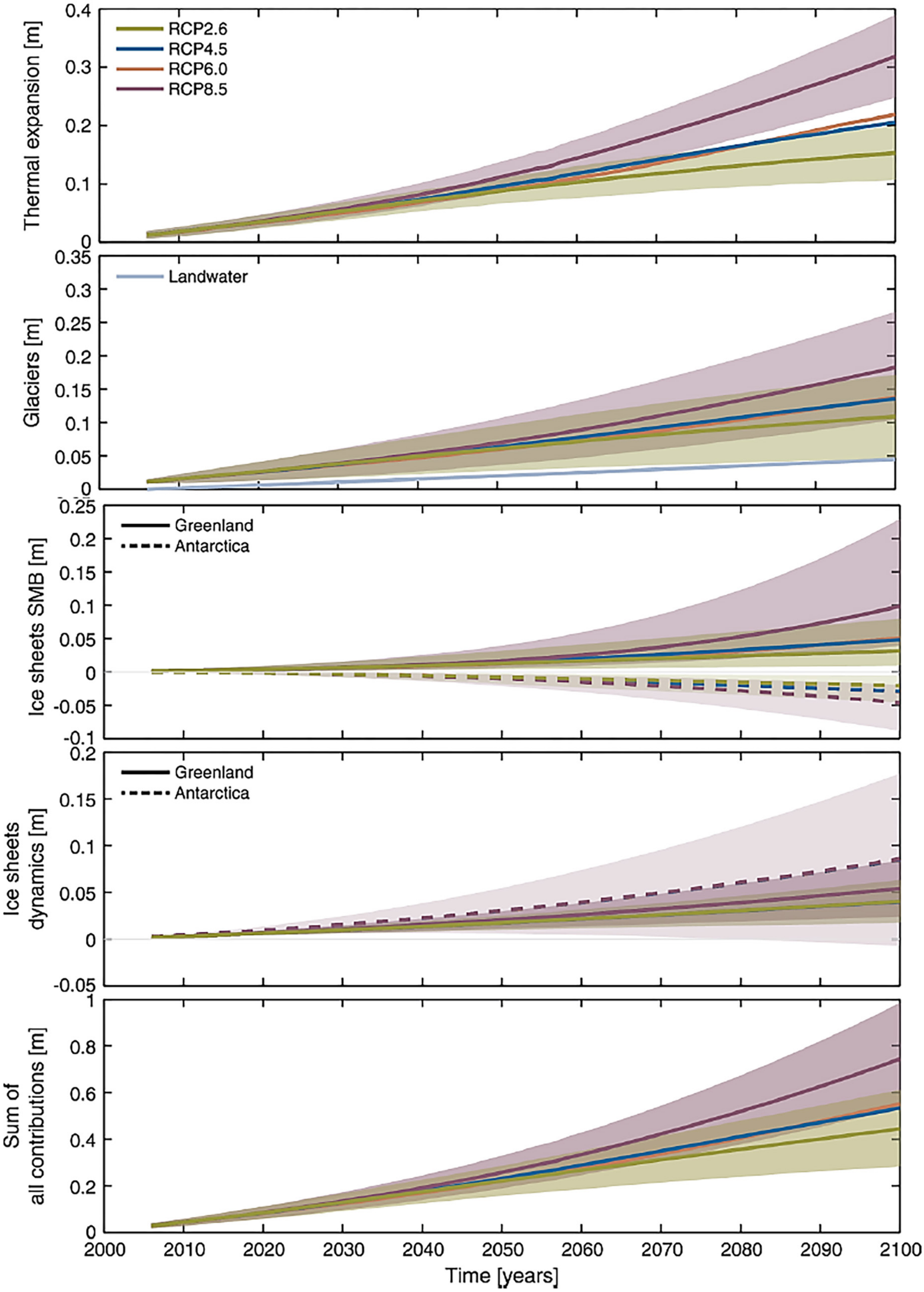

Figure 25: Contributions to 21st century global mean sea level rise (thick coloured lines) calculated using the results of individual climate models for all four emission scenarios. (a) Global average ocean thermal expansion. (b) Glacier mass loss. (c) Changes in the surface mass balance of the Greenland and Antarctic ice sheets. (d) Ice sheet dynamical contributions. (e) Sum of all contributions. For the RCP8.5 and RCP2.6 scenarios, the multi-model mean values with 5 to 95% uncertainty ranges (shaded areas) are shown but for RCP6.0 and RCP4.5 scenarios, only the multi-model mean values are shown.

b) Sea level rise projections study

Projections of the regional sea level change along the Malaysian coastline during the 21st century were followed to Church et al. (2011)[35], by combining published global mean sea level (GMSL) contributions by the IPCC AR5[34], and regional sea level contributions, which include dynamic sea levels, are processed by the CSIRO sea level group and various sea level fingerprints based on Mitrovica et al. (2011)[42]. In total, there are 29 models of CMIP5 used in this study, but not all of the CMIP5 models are available for developing the sea level projections for Malaysia. In general, there is less data available for RCP 6.0 compared to other RCPs and for both RCP 4.5 and 8.5 only one (1) model of CMIP5 is not available (Table 6).

Table 6. CMIP5 models used in this study for dynamic sea level under four RCPs. Ticks refer to available models and crosses indicate models for which the required data was unavailable.

Model	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
ACCESS1-0	✗	✓	✗	✓
ACCESS1-3	✗	✓	✗	✓
CanESM2	✓	✓	✗	✓
CCSM4	✓	✓	✓	✓
CESM1-BGC	✗	✓	✗	✓
CESM1-CAM5	✓	✓	✓	✗
CMCC-CESM	✗	✗	✗	✓
CMCC-CMS	✗	✓	✗	✓
CNRM-CM5	✓	✓	✗	✓
CSIRO-MK3-6-0	✓	✓	✓	✓
FGOALS-g2	✓	✓	✗	✓
FIO-ESM	✓	✓	✓	✓
GFDL-CM3	✓	✓	✓	✓
GFDL-ESM2G	✓	✓	✓	✓
GFDL-ESM2M	✓	✓	✓	✓
GISS-E2-R	✓	✓	✓	✓
HadGEM2-CC	✗	✓	✗	✓
HadGEM2-ES	✓	✓	✓	✓
INMCM4	✗	✓	✗	✓
IPSL-CM5A-LR	✓	✓	✓	✓
IPSL-CM5A-MR	✓	✓	✗	✓
IPSL-CM5B-LR	✗	✓	✗	✓
MIROC5	✓	✓	✓	✓
MIROC-ESM-CHEM	✓	✓	✓	✓
MIROC-ESM	✓	✓	✓	✓
MPI-ESM-LR	✓	✓	✗	✓
MRI-CGCM3	✓	✓	✓	✓
NorESM1-ME	✓	✓	✓	✓
NorESM1-M	✓	✓	✓	✓
TOTAL	**21**	**28**	**16**	**28**

42 Mitrovica, J.X., Gomez, N., Morrow, E., Hay, C., Latychev, K. & Tamisiea, M.E. (2011). On the robustness of predictions of sea level fingerprints, *Geophysical Journal International* 187(2): 729-742.

Regional sea level projections, derived from the CMIP5 models around Malaysia over the years of 2080-2099 relative to 1986-2005, under four RCP scenarios, are shown in Figure 26. In general, sea level rises are highest under the business-as-usual scenario RCP 8.5 (Figure 26d), and weakest under the strong-mitigation scenario RCP 2.6 (Figure 26a), with intermediate values under the other two scenarios – RCPs 4.5 and 6.0 (Figure 26b, c).

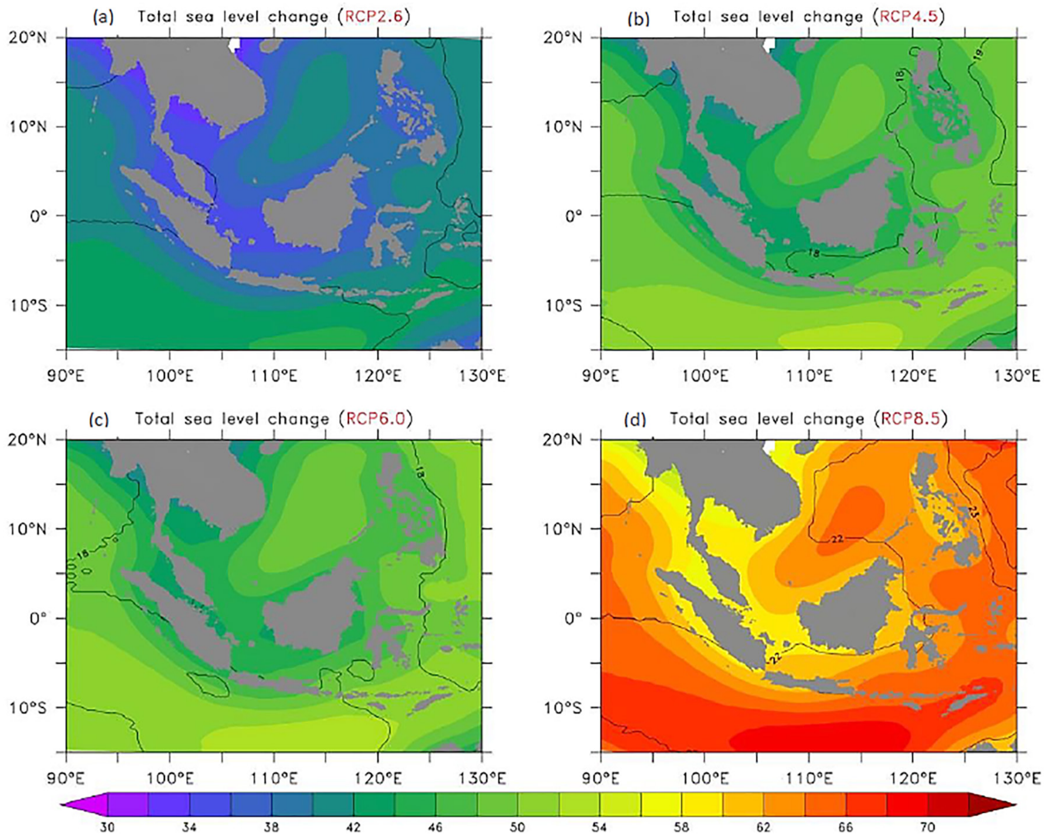

Figure 26: Total regional variation in projected sea levels (cm) for the Malaysian region over 2080-2099 relative to 1986-2005 under four emission scenarios, with uncertainty indicated by contours.

The largest contributions from global to regional sea level change come from ocean thermal expansion and the loss of mass from glaciers, with growing contributions from the ice sheets, particularly in the second half of the 21st century and beyond. The projections of dynamic sea level are quite uniform, exhibiting a variation of only about 1-2 cm along the Malaysian coastline. As Malaysia is in the far field of the various fingerprints associated with loss of mass from the glaciers, i.e. Greenland Ice Sheet and Antarctic Ice Sheet, the combined sea level fingerprint under RCP 8.5 has smooth regional patterns around Malaysia. There is a gradient in the SE-NW direction in the central and southern parts of the South China Sea (SCS), with larger values (~2 cm) along the coastline of East Malaysia. Additionally, Glacial Isostatic Adjustment (GIA) induces a stronger sea level gradient between the Malaysian coastline and the interior of the SCS. There is a local maximum of GIA-induced sea level change of -1 to approximately 0 cm centred at 115°E, 15°N. In contrast, it is about -5 cm along the East Malaysia coast, and about -7 cm along the coast of Peninsular Malaysia.

Observed sea levels in the historical period from tide gauges and satellite altimeters, associated with projected sea levels from 1996 to 2100 showed sea level change and variability in a consistent value. The observed sea levels for both the tide gauge (with and without the seasonal cycle) and altimeter have been added to the four RCP projections, measured hereafter with respect to the IPCC baseline 1986-2005, to illustrate (1) how well the observed records track both the historical multi-model mean simulation and projections over the recent period and; (2) how the observed interannual variability explains departure from the mean projections, where the inter-annual variability of individual models has been effectively removed by averaging across the models.

Overall, sea level projections for 21 tide gauge stations along the Malaysian coastline show similarly for all RCPs scenarios to the GMSL projections in Figure 27, with seasonal to inter-annual variability driven by the monsoons and the major Indo-Pacific climate variability such as El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). These two influences are the main discriminating feature across locations for timelines 2020, 2050 and 2100. For more details on a 10-year interval of SLR projections, please refer to the SLR projections report by NAHRIM (2019)[25]. In addition to the projection's figures, a table of sea level projections is also provided for each decade of the 21st century. It is possible to extract sea level projections similar to the locations of JUPEM's tide gauge which are presented in Impact of Climate Change – Sea Level Rise Projections for Malaysia 2017[25]. The graph provides the projected sea level rise shows 5-95% range due to inter-annual and seasonal variability. 5% range is subtracted from the lower range of RCP 2.6 and the 95% is added to the upper range of RCP 8.5. The tables give the central projected sea level rise relative to 1986-2005 with the 17-83% uncertainty range for each decade to 2100.

c) Scenario-based and coastal inundation

SLR was projected at selected tidal stations for the current timeline (2022), by 2050, and by 2100 with respect to sea level in 2015 as a baseline, which was based on RCP8.5 and IPCC AR5 (Table 7). The ranges of maximum sea level values were estimated at the same stations for the same period (Figure 27). The Malaysian coastline was projected to experience a maximum SLR of 0.22-0.25 m by 2050 and 0.67-0.74 m by 2100. In general, Sabah could face a higher SLR than Sarawak and Peninsular Malaysia. SLR of up to 0.25 m and 0.74 m are expected at the Kudat coastline by 2050 and 2100, respectively. In Peninsular Malaysia, the west coast (with a projected rise of 0.22-0.23 m by 2050 and 0.67-0.69 m by 2100) was projected to face a lower SLR than the east coast (0.23 m by 2050 and 0.70-0.71 m by 2100). Also, Sarawak coastlines could face SLR of 0.24 m by 2050 and 0.71-0.72 m by 2100.

Table 7. Projected SLR for current timeline, 2050 and 2100. Source: NAHRIM (2023)[43].

Tidal Station	Projected SLR (m)			Remarks
	Current (2022)	By 2050	By 2100	
Pulau Langkawi	0.07	0.22	0.68	West Coast of Peninsular Malaysia
Pulau Pinang	0.07	0.22	0.68	
Lumut	0.07	0.22	0.67	
Pelabuhan Klang	0.07	0.22	0.68	
Tanjung Keling	0.07	0.23	0.69	
Kukup	0.07	0.23	0.70	
Johor Bahru	0.07	0.23	0.70	
Tanjung Sedili	0.07	0.23	0.70	East Coast of Peninsular Malaysia
Pulau Tioman	0.07	0.23	0.71	
Tanjung Gelang	0.07	0.23	0.71	
Chendering	0.07	0.23	0.70	

43 National Water Research Institute of Malaysia (NAHRIM). (2023). Available at: mycoast.nahrim.gov.my. Accessed on: 7 January 2023.

Tidal Station	Projected SLR (m)			Remarks
	Current (2022)	By 2050	By 2100	
Getting	0.07	0.23	0.70	Sarawak
Miri	0.07	0.24	0.72	
Bintulu	0.07	0.24	0.71	
Sejingkat	0.07	0.24	0.72	
Labuan	0.07	0.24	0.73	Wilayah Persekutuan Labuan
Kota Kinabalu	0.07	0.25	0.73	Sabah
Kudat	0.08	0.25	0.74	
Sandakan	0.07	0.25	0.73	
Lahat Datu	0.07	0.24	0.73	
Tawau	0.07	0.24	0.72	

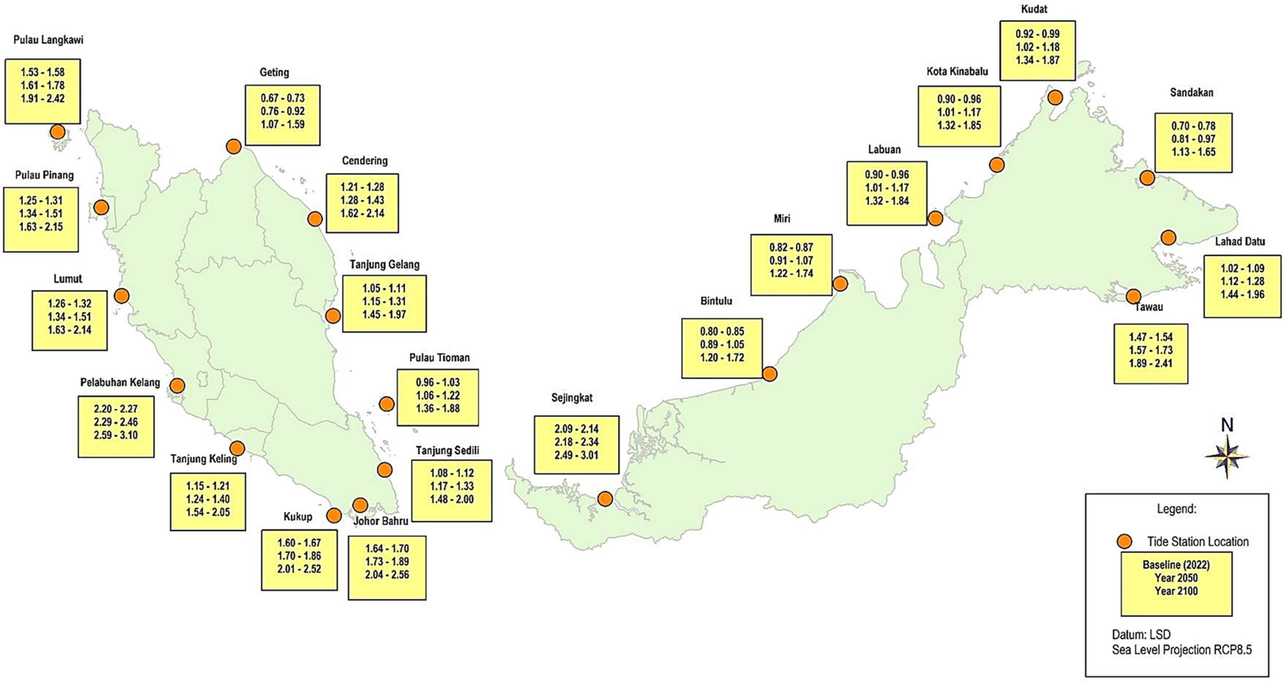

Figure 27: Projected range of sea level values (metres –with added sea level rise value from MSL) at selected tidal stations under the current timeline, 2050 and 2100. Source: NAHRIM (2023)[43].

Coastal inundation along Malaysia's shorelines was assessed and presented for the current timeline (2022), by 2050 and by 2100 (Table 8 and Figure 28). The potential total inundated areas could increase by 16.9% and 76.9% by 2050 and 2100 respectively, compared to the current timeline. The most vulnerable coastline was projected to be located in Sabah, followed by Selangor in Peninsular Malaysia and Sarawak. The west coast of Peninsular Malaysia along the Straits of Malacca could be more vulnerable to coastal flooding compared to the east coast of Peninsular Malaysia.

Table 8. Projected inundation areas in Malaysian coastlines under current timeline, 2050 and 2100.

State	Total Area of Inundation due to Sea Level Rise (RCP 8.5) km^2		
	Current timeline (2022)	2050	2100
Perlis	11.5	17.1	53.1
Kedah	364.7	441.9	661.3

State	Total Area of Inundation due to Sea Level Rise (RCP 8.5) km²		
	Current timeline (2022)	2050	2100
Pulau Pinang	121.5	155.6	319.0
Perak	750.7	857.6	1185.8
Selangor	1100.6	1196.1	1545.6
Negeri Sembilan	18.9	23.8	40.6
Melaka	25.0	32.1	73.3
Johor	813.5	897.2	1166.4
Pahang	36.1	45.4	108.1
Terengganu	101.9	128.5	237.9
Kelantan	35.0	55.8	81.8
Sabah	1511.3	1771.0	2512.1
Labuan	4.3	5.0	10.6
Sarawak	358.1	516.0	1299.3
TOTAL	**5253.0**	**6143.0**	**9294.9**

In summary, the projected coastal inundation areas due to SLR along Malaysia's coastline could increase from the current 5,253.0 km^2 to 6,143.0 km2 and 9,294.9 km^2 by 2050 and 2100, respectively.

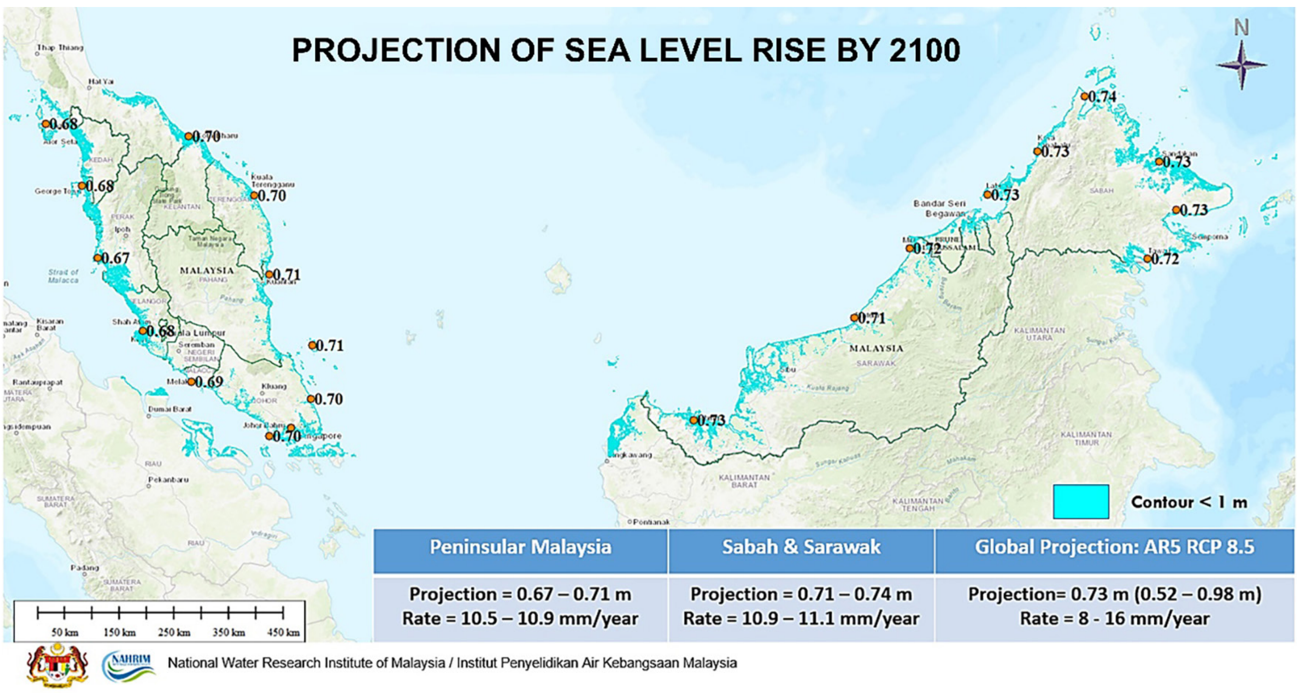

Figure 28: Coastal inundation projected using RCP8.5 in timeline of 2100 along the Malaysian coastline. Source: NAHRIM (2023)[41].

d) SLR impact on the population

Malaysia is exposed to approximately 144 flood events on an annual average, based on JPS studies. The consequence of these fluvial, monsoonal, coastal, and flash floods is that about 33,298 km^2 (10.1%) of the country's land area with 5.7 million people (21% of the population) are affected (NC4, n.d). Coastal flooding due to SLR via coastal floods was projected to increase the vulnerability based on the projected coastal inundation areas by 2100. Studies carried out for Peninsular Malaysia and Labuan found around 16.6 million people could be affected by coastal floods due to SLR by 2100. The number of affected populations was estimated based on an annual population growth of 1.3%, taking 2021 as a baseline.

e) **Adaptation measures: coastal flood risk management**

The development of Malaysia flood mitigation plans and infrastructure projects has been one of the consistent approaches by DID Malaysia to relieve the population from the effects of heavy rainfall and runoff. To strengthen these approaches, NAHRIM has initiated updated the Malaysian sea level rise projections and its coastal inundation risk maps. Currently, there are 76 flood mitigation projects being implemented throughout the country, while 32 and 13 projects are respectively, under planning and study, respectively. There are 60 hazard maps, having been developed between 2010 and 2022 at different river basins, to support these projects.

The DID Malaysia has also installed a network of telemetric rainfall and river water level stations to monitor the rainfall and river water levels at the major river basins. This telemetric approach assists flood forecasting and monitoring work. The National Flood Forecasting and Warning Programme (NaFFWS) was initiated to develop a system to forecast monsoon floods and disseminate flash flood warnings, based on weather forecast data from the Malaysia Meteorological Department (MMD).

15. Malaysian Stakeholders of Climate Change & Health

15.1 Ministry of Natural Resources and Environmental Sustainability

The Ministry of Natural Resources and Environmental Sustainability is leading the effort towards Sustainable Malaysia 2030. There are 30 initiatives which are built upon four thrusts: empowered governance, green growth, strategic collaboration and social inclusiveness, covering the atmosphere (air), hydrosphere (water), lithosphere (land) and biosphere (living things). The ministry plans to collaboratively enhance planetary health.

The main functions are:

The Ministry of Natural Resources and Environment Sustainability will facilitate synergy between the main aspects of environment management (under Department of Environment), water management which were previously separated, namely water resources and water services. The Department of Irrigation and Drainage was responsible for water resources while the National Water Services Commission (SPAN) was responsible for monitoring water services involving supply and irrigation.

15.2 Malaysian Meteorological Department (MET Malaysia)

The Malaysian Meteorological Department is under the purview of the Ministry of Natural Resources and Environmental Sustainability. METMalaysia provides services as the main agency for areas of meteorology, climate and geophysics.

The main roles are in providing:

- Weather forecasts: Country, state, district, towns, tourist destinations.
- Marine Forecast: Waters, shipping.
- Earthquake: Earthquake alert.
- Observations:

  i. Surface temperature, rainfall, visibility, relative humidity.
  ii. Radar: Malaysia, Peninsula, Sabah & Sarawak.
  iii. Satellite: Himawari-8, Feng Yun.
  iv. Atmospheric Science: Suspended particulates (TEOM PM-10 and PM-2.5), ultraviolet index (UVI), greenhouse gases, ozone, space weather and acid deposition.
  v. Climate: Fire Danger Rating System. 10-days bulletin, weather analysis, seasonal forecasts, long range weather outlook, latest El Nino Forecast, monthly El Nino forecasts

15.3 National Water Research Institute of Malaysia (NAHRIM)

The main mission of NAHRIM is to serve as a Centre of Excellence in providing services on water and environmental management to ensure sustainable growth for improvement of quality of life and wellbeing[44].

The main functions of NAHRIM are:

- Conducting basic and applied research within water sectors such as river basins, water resources and climate change, coastal and oceanography, hydrogeology and water quality and environment.
- Providing expert consultancy services pertaining to water and its environment for the public and private sector.
- Providing advisory role in water-related fields.
- As a referral centre for water and environment-related research at the national level as well as actively participating in bilateral or multilateral research at the international level.

Apart from that, NAHRIM plays a crucial role in conducting hydro-climate research in Malaysia. The specific activities and projects of NAHRIM have evolved since then, but the institute's roles generally include:

i. Climate Modelling and Projection - NAHRIM is involved in developing and updating climate models to project future hydro-climate conditions in Malaysia. This includes incorporating the latest scientific findings, such as those presented in reports such as the Intergovernmental Panel on Climate Change (IPCC) assessments.

ii. Data Collection and Analysis - The institute is engaged in collecting and analysing projected hydro-climate data, including future rainfall patterns, temperature trends, river flows, and other relevant parameters. This data serves as a foundation for understanding current conditions and making informed projections.

iii. Impact Assessment - NAHRIM assesses the potential impact of climate change on water resources, river basins, and coastal areas. This involves evaluating how changes in temperature, precipitation, and sea levels may affect water availability, quality, and overall hydrological systems.

iv. Vulnerability and Adaptation Assessment - The institute conducts studies to identify vulnerabilities within different regions or sectors due to changing hydro-climatic conditions. Additionally, NAHRIM explores and recommends adaptation strategies to mitigate the adverse effects of climate change on water resources and related infrastructure.

v. Research Collaboration - NAHRIM collaborates with other research institutions, governmental bodies, and international organisations to enhance the scientific understanding of hydro-climate dynamics. Collaborative efforts often contribute to more comprehensive and accurate research outcomes.

vi. Policy Support - Findings from NAHRIM's research are utilised to inform and support the development of policies related to water resource management, climate adaptation, and sustainable development in Malaysia.

vii. Capacity Building - The institute is involved in capacity-building initiatives, including training programs and knowledge dissemination, to enhance the expertise of professionals and stakeholders involved in hydro-climate research and management.

15.4 Ministry of Health

The Ministry of Health Malaysia is the lead agency in health care provider services. The Occupational Safety and Health Unit, Disease Control Division has been appointed as the focal point for any climate change issues in collaboration with the Environmental Health Research Centre (EHRC), Institute of Medical Research based in the National Institute of Health (NIH) Malaysia. The role of MOH in relation to climate change is to prepare input related to the Public

[44] National Water Research Institute of Malaysia (NAHRIM). (2020). Available at: http://www.nahrim.gov.my/about/introduction/visionmissionobjectives.html. Accessed on 19 March 2021.

Health for Biennial Update Reports (BURs) and National Communication to UNFCC, especially on the aspect of climate change health impacts, vulnerability and adaptation assessment.

There are several programs and activities carried out and implemented under the MOH that take into account the direct and indirect impacts of climate change on public health, such as:

- Vector-borne disease control program.
- Food & water-borne disease control program.
- Sustainability program in healthcare facilities.

15.5 National Security Council (NSC)

Since its establishment in 1971, the National Security Council (NSC) has served as the principal agency in coordinating security-related strategies [45]. The NSC's source of authority is NSC Directive No. 1, which is based on the Emergency (Essential Powers) Act 1979 which clarifies the NSC's formation and responsibilities. In essence, the NSC is in charge of coordinating national security strategies and determining the direction of security issues. The NSC has formulated the National Security Policy, the principal policy in confronting various security threats which have become dynamic and complex. Under the National Security Policy, natural disaster has been stated as one out of 13 National Security Issues. The NSC has established the National Security Council Directive No. 20 (NSC20) which outlines the standard operating procedures for disaster management.

15.6 National Disaster Management Agency (NADMA)

National Disaster Management Agency or NADMA is the Malaysia's National Focal Point for Disaster Management[46]. NADMA was officially formed on 1st October 2015, after the major flood incident in Kelantan, taking over the roles of the NSC in disaster management, Post-Flood Recovery Unit of the Prime Minister's Department and the Special Malaysia Disaster Assistance and Rescue Agency (SMART).

Other key roles of NADMA:

- Formulation of the National Disaster Management Policy[47].
- Regulate the implementation of policies.
- Coordinate the Disaster Risk Reduction (DRR) Initiative.
- Implement public awareness programmes.
- Implement After Action Review (AAR).
- Managing Disaster Relief Trust Funds.
- Secretariat of the National Disaster Management Committee.
- Head of Humanitarian Assistance Disaster Relief Delegation 10.
- Deployment of SMART teams.

15.7 State and local authorities

There are 13 state governments in Malaysia. Local governments are generally under the exclusive purview of the state governments as provided in the Malaysian constitution, except for local governments in the federal territories. The Federal Ministry of Housing and Local Government plays a role in co-ordinating and standardising the practices of local governments across the country.

The local governments provide basic amenities, as well as collect and manage waste. The planning and the development of the areas under its jurisdiction is also one of the local

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[45] Majlis Keselamatan Negara. Sejarah Penubuhan. Available at: https://www.mkn.gov.my/web/ms/sejarah-mkn/ Accessed on 17 April 2021.

[46] National Disaster Management Agency Malaysia (NADMA). Available at: https://www.nadma.gov.my/en/corporate/history-establishment-nadma. Accessed on 18 February 2022.

[47] Malaysia Disaster Management Reference Handbook. (2019). Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/Malaysia%20Disaster%20Management%20Reference%20Handbook%202019.pdf). Accessed on 10 May 2022.

government's main functions. The local government has the authority to collect taxes, create laws, grant licenses and permits[48].

Local Agenda 21 (LA21) is a global action plan or blueprint for sustainable development at a local level, which was adopted at the Earth Summit in Rio de Janeiro 1992. LA21 represents a common consensus and political commitment of countries across the world on implementing sustaining development and environmental cooperation. Kuala Lumpur City Hall and Johor Bharu City Hall are examples of local authorities in Peninsular Malaysia that have actively introduced many initiatives to integrate the economic, social and environmental solutions in their urban development plans[49]. The Municipal Council of Seberang Perai, Penang has succeeded in implementing the Local Agenda 21 to its community[50]. Forging strong partnerships between public, private and communities, the Seberang Perai Municipal Council introduced various initiatives and activities such as the Zero Waste Programs in Schools and communities, recycling programs, community farming, box drink collections, "Eat Till Finish" campaigns and others. The council has received global recognition and was given an award at the 11th Global Forum on Human Settlements Awards Ceremony held in Quito, Ecuador in October 2016.

16. Health Impacts of Climate Change

Changes in the greenhouse gas concentrations and other drivers alter the global climate and bring about a myriad of human health consequences. Environmental consequences of climate change, such as extreme heat waves, rising sea-levels, changes in precipitation resulting in flooding and droughts, intense hurricanes, and degraded air quality, directly and indirectly affect the physical, social, and psychological health of humans. For instance, changes in precipitation are creating changes in the availability and quantity of water, as well as resulting in extreme weather events such as intense hurricanes and flooding. Climate change can be a driver of disease migration, as well as exacerbate health effects resulting from the release of toxic air pollutants in vulnerable populations such as children, the elderly, and those with asthma or cardiovascular disease.

16.1 Health impacts of temperature rise

a) Heat related illnesses

Climate change is the physical manifestation of climate change and extreme weather. It is cross-sectoral in nature, involves more than environmental issues, affecting economic growth and human wellbeing (Figure 29).

Heat related illnesses is a spectrum of disorders ranging from minor (heat oedema, heat rash, heat syncope, heat cramps and heat exhaustion) to a major form, which is heat stroke. In cases of heat strokes, there is a 70% mortality[51]. Vulnerable groups are athletes, the military, police, fire fighters, young children left in vehicles in exposed to the sun, the elderly, people with chronic diseases, as well as outdoor workers such as construction workers and farmers and municipal workers[52]. The impacts to health are increased in the number of mortality and heat-related illnesses (HRI). A study showed

48 Local Government Department, Ministry of Housing and Local Government, Malaysia. (2020). Local Government Department.

49 Abidin, N.I., Zakaria, R., Aminuddin, E., Saar, C.C., Munikanan, V., Zin, I.S. & Bandi, M. (2016). Malaysia's local agenda 21: Implementation and approach in Kuala Lumpur and Johor Bharu. *The IIOAB Journal* 7(1): 554-562.

50 Maimunah, M.S. (2016). Implementing Local Agenda 21. The 11th Global Forum on Human Settlements Award Ceremony 2016. Quito, Ecuador.

51 Ministry of Health. (2016). Director General of Health. Heat Related Illnesses in Malaysia.

52 Zawiah M., Rosnah, I., Noor Hassim, I. & Jamal, H.H. (2019). Effects of hydration practices on the severity of heat-related illness among municipal workers during a heat wave phenomenon. *Medical Journal of Malaysia* 74(4): 275-280.

53 Toloo, G., FitzGerald, G., Aitken, P., Verall, K. & Tong, S. (2013). Evaluating the effectiveness of heat warning systems: systematic review of epidemiological evidence. *International Journal of Public Health* 58: 667-681.

54 Wolf, T. & McGregor, G. (2013). The development of a heat wave vulnerability index for London, United Kingdom. Weather and Climate Extremes 1:59-68.

that heatwaves kill thousands of people every year across the world[53]. Europe and Russia had recorded high mortality & morbidity due to heat related illnesses and heat strokes[54]. Malaysia's hot and humid weather increases the risk of heat stress, especially on the exposed population. In 2016, there were several cases of heat stroke following unpredictable hot and dry weather in Malaysia[55,56].

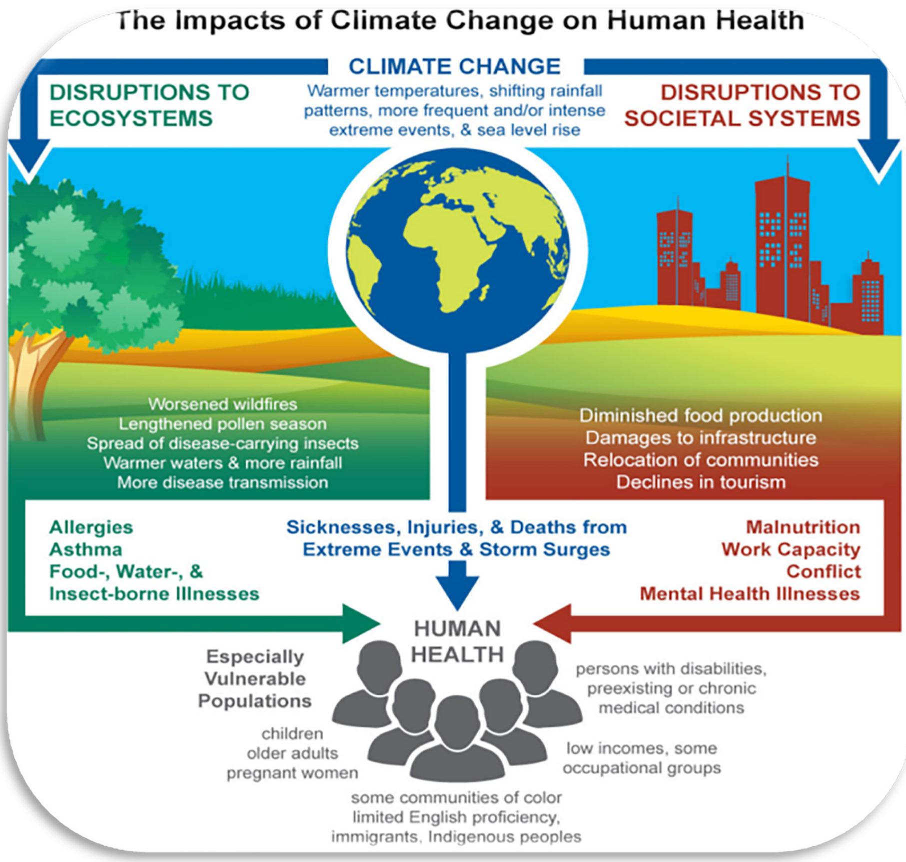

Figure 29: The impacts of climate change on human health.
Source: Ocko (2016)[57].

From a public health perspective, heat-related illnesses are preventable. It is crucial to learn the symptoms and the necessary steps to be taken if anyone shows signs of having a heat-related illness[58].

Heat rashes present as red clusters of small blisters that appears like pimples, usually on the neck, chest, groin and elbow creases. A person suffering from heat rash should stay in a dry, cool place, while keeping the rashes dry. Baby powder may be used to soothe the rash.

Sunburn presents as painful, red and warm skin, sometimes producing blisters on the skin. A person must stay out of the sun until the sunburn heals. He can also put cool

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55 Ministry of Health, Malaysia. (2016). Clinical guidelines on Management of Heat Related Illness at health clinic and Emergency and Trauma Department. Available at: https://www.moh.gov.my/moh/resources/Polisi/GARISPANDUAN_PENGURUSAN_KES-KES_YANG_BERKAITAN_DENGAN_CUACA_PANAS.pdf. Accessed on 12 May 2022.

56 Arsad, F. S., Hod, R., Ahmad, N., Baharom, M., & Tangang, F. (2022). The Malay-Version Knowledge, Risk Perception, Attitude and Practice Questionnaire on Heatwaves: Development and Construct Validation. *International Journal of Environmental Research and Public Health* 19(4): 2279.

57 Ocko. (2016). The Impacts of Climate Change on Human Health – a Sobering New Report. Available at: https://blogs.edf.org/climate411/2016/04/05/the-impacts-of-climate-change-on-human-health-a-sobering-new-report/ Accessed on: 17 March 2022.

58 Center for Disease Control, Atlanta, USA. (2017). Heat Related Illnesses. Available at: https://www.cdc.gov/disasters/extremeheat/pdf/Heat_Related_Illness.pd. Accessed on 17 March 2022.

cloths on the sunburn areas or take a cool bath. Moisturising lotion can be applied to the sunburned areas. He must take care as not to break the blisters, as to prevent infections.

Heat cramps present as heavy sweating during intense exercise, as well as muscle pain or muscle spasms. A person must stop the activities and move to a cool place. He must rehydrate himself by drinking water or a sports drink. Emergency medical attention is required if the spasms persist for more than one hour or if the person has heart problems.

Heat exhaustion presents as heavy sweating but cold, pale and clammy skin. The pulse is rapid but weak. He may experience nausea or vomiting, muscle cramps, tiredness, weakness, dizziness, headache, or fainting. The clothes must be loosened. A cool, wet towel can be applied to the affected areas, or he can take a cool bath. He may take sips of water. However, if a person is vomiting, or the symptoms worsen or persist for more than an hour, then emergency medical help is required.

Public awareness should be enhanced to increase the community's understanding that prolonged exposure to hot weather without drinking sufficient water could be detrimental to one's health, even life threatening, especially for high-risk groups such as children, senior citizens, and those with chronic diseases. The public are advised to take preventive measures, such as avoiding being outside under the hot sun, between 11am and 4pm because this is the time when the heat is at its highest.

Ensuring adequate hydration is important, by drinking at least eight glasses of water a day and to avoid sugary, caffeinated and carbonated drinks as they are bad for hydration. High-risk groups such as infants, children, and the elderly must drink enough water to avoid dehydration.

b) Vector-borne diseases

Globally, among the vector-borne diseases, malaria is the major killer, causing an estimated 620,000 deaths in 2017. Most of these deaths occurred in Africa. The second major vector-borne disease is dengue, which caused 40,500 deaths, mostly in Asia[59].

Malaysia is a hyper endemic country for dengue. Dengue epidemics occur every 5-8 years in Malaysia; 1974, 1982,1987,1991,1998 and increasing till 2001. There was a slight reduction in 2011 and 2012, but it rose again in 2013. In 2015, 120,836 cases of dengue with an incidence rate of 396.4 per 100,000 people. In 2019 a total of 130,301 dengue cases were reported in Malaysia, a 60% jump from 2018[60]. The variation in the number of dengue cases across districts in Peninsular Malaysia underscores the complex interplay of factors contributing to dengue transmission (Figure 10). The potential impacts of climate change on dengue indicate increased climatic suitability for transmission and expansion of the geographic regions at risk during this century[61].

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59 Rocklov, J. & Dubrow, R. (2020). Climate change: an enduring challenge for vector-borne disease prevention and control. *Nature Immunology* 21: 479-483.

60 Ministry of Health. (2020). Health Facts 2020. Available at: https://www.moh.gov.my/moh/resources/Penerbitan/Penerbitan%20Utama/HEALTH%20FACTS/Health%20Facts%202020.pdf. Accessed on 7 July 2022.

61 Sivaratnam, L., Wong, C.M., Selimin, D.S., Hod., R., Abu Bakar, S., Ghazi, H.F. et al. (2022). Impact of climate change on abundance, distribution and survival of Aedes species: Systematic Review. *Global Journal of Public Health Medicine* 4(1): 579-607.

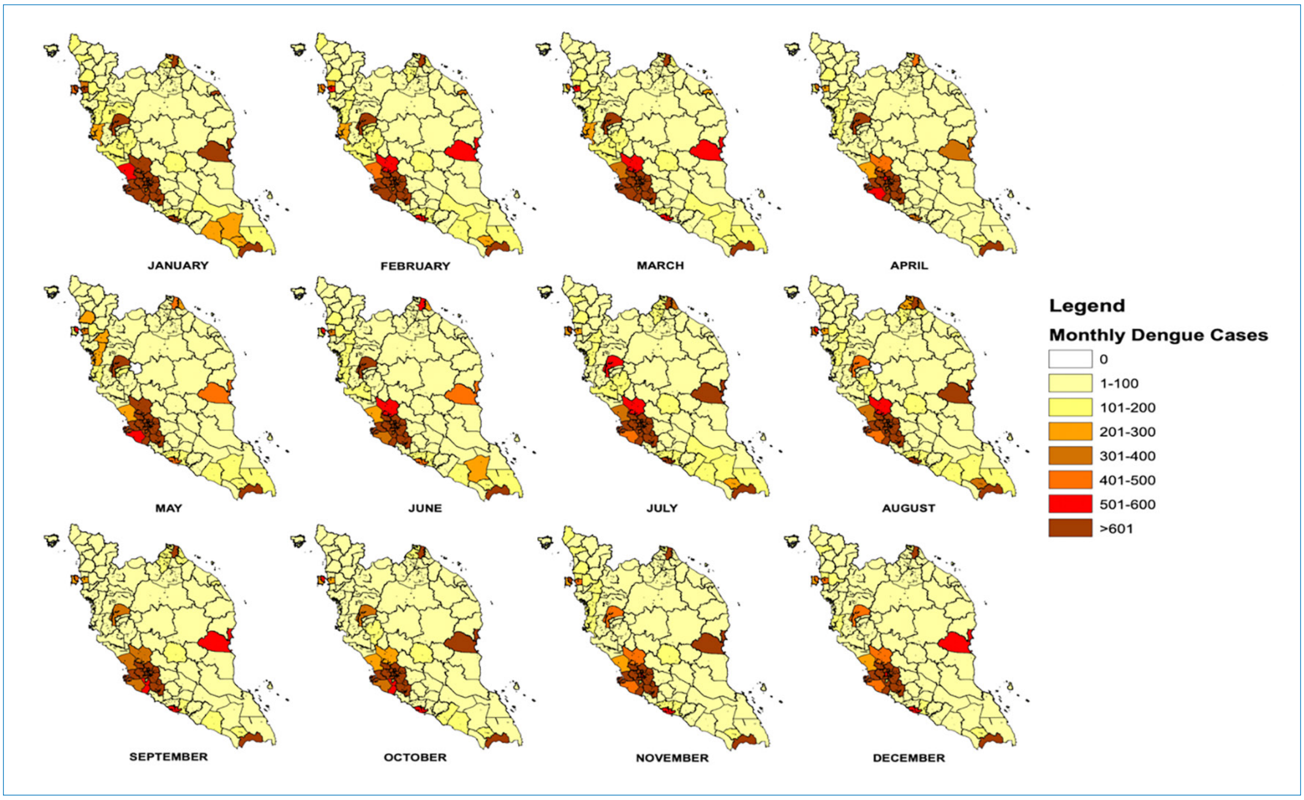

Figure 30: Spatial-Temporal Distribution of Dengue Cases by Using Summarised Monthly Data in Peninsular Malaysia for the Study Period of 2016 to 2020

The correlation between temperature and dengue cases has been extensively studied, with the majority of research indicating a positive relationship[62,63]. Elevated temperatures are linked to increased vector biting rates, a shorter extrinsic incubation period for the dengue virus, and faster egg-to-adult development times for Aedes mosquitoes[64]. These findings underscore the potential for temperature increases to accelerate the transmission of dengue. Additionally, rising global temperatures have been associated with the expansion of the *Ae. aegypti* vector into new regions, further increasing the risk of dengue transmission. However, there are conflicting findings regarding the precise impact of temperature on dengue transmission. Some studies suggest that extremely high temperatures may negatively affect virus transmission, while others point to an optimal temperature range for Aedes growth.

Land Surface Temperature (LST), which is measured using thermal remote sensing images from Landsat, has also shown a positive correlation with dengue cases in certain studies. This indicates the complexity of the relationship between temperature and dengue incidence[65]. Given the dynamic nature of the temperature-dengue relationship, further research is necessary to bridge existing gaps in understanding and to inform more targeted and effective dengue prevention and control strategies. This information is crucial for policymakers to develop targeted strategies for dengue prevention and control, emphasising the importance of integrated vector management and community engagement in affected areas.

62 Noureldin, E., & Shaffer, L. (2019). Role of climatic factors in the incidence of dengue in Port Sudan City, Sudan. *Eastern Mediterranean Health Journal,* 25(12), 852–860.

63 Kakarla, S. G., Caminade, C., Mutheneni, S. R., Morse, A. P., Upadhyayula, S. M., Kadiri, M. R., & Kumaraswamy, S. (2019). Lag effect of climatic variables on dengue burden in India. *Epidemiology and Infection, 147*

64 Pham, H. V., Doan, H. T. M., Phan, T. T. T., & Tran Minh, N. N. (2011). Ecological factors associated with dengue fever in a Central Highlands province, Vietnam. *BMC Infectious Diseases, 11,* 1–6.

65 Roslan, N. S., Latif, Z. A., & Dom, N. C. (2017). Dengue cases distribution based on land surface temperature and elevation. *2016 7th IEEE Control and System Graduate Research Colloquium, ICSGRC 2016 - Proceeding, December 2017,* 87–91.

Malaria is another vector borne disease in Malaysia, the vector being *Anopheles* sp. mosquitoes. .Climate can affect the transmission dynamics, geographic spread and re-emergence of vector-borne diseases through multiple pathways, including direct effects on the pathogen, the vector, non-human hosts and humans. Arthropods are ectotherms, in which when temperature increases, the rate of pathogen development will also increase. Therefore, with increasing temperature, there will be an increase in vector abundance, feeding activities and survival rate. In addition to having direct effects on individual species, climate change can alter entire ecosystem habitats (including urban habitats), in which vectors or non-human hosts may thrive or fail.

16.2 Health impacts of increased rainfall and flooding

Changes in the greenhouse gas concentrations and other drivers alter the global climate and bring about a myriad human health consequences. Environmental consequences of climate change, such as extreme heat waves, rising sea levels, changes in precipitation resulting in flooding and droughts, intense hurricanes, and degrading air quality directly and indirectly affect the physical, social, and psychological health of humans (Figure 30). For instance, changes in precipitation are creating changes in the availability and quantity of water, as well as resulting in extreme weather events such as intense hurricanes and flooding. Climate change can be a driver of disease migration, as well as exacerbate health effects resulting from the release of toxic air pollutants in vulnerable populations such as children, the elderly, and those with asthma or cardiovascular disease.

16.2.1 Drowning and accidents

Flood is the most devastating natural disaster experience in Malaysia. Throughout Malaysia, including Sabah and Sarawak, there are a total of 189 river basins (89 of the river basins are in Peninsula Malaysia, 78 in Sabah and 22 in Sarawak), with the main channels flowing directly to the South China Sea and 85 of these river basins are prone to recurrent flooding events. The estimated area vulnerable to flood disasters is approximately 29,800 km^2,or 9% of Malaysia's total land area and is affecting 4.82 million people, which is around 22% of the total population of the country. Drowning is one of the leading causes of death during times of flood. Children and young people are especially at increased risk of drowning. The World Health Organization (WHO) reports that, globally, over half of all drowning deaths are among those aged under 25 years.

Flooding is the most destructive of all natural disasters with respect to the number of people affected and the resultant economic losses. In 2018, floods resulted in the deaths of 2,859 people and affected a further 35.4 million people. Drowning is one of the leading causes of death during times of flood, with mortality and morbidity likely to grow with extreme weather and floods increasing due to the effects of climate change. In 2018, flooding resulted in the deaths of 504 people in India, 220 in Japan, 199 in Nigeria and 151 in the Republic of Korea. Examination of flood-related drowning deaths between 1980 and 2009 identified 539,811 deaths with motor vehicle incidents and the male gender is associated with increased mortality in developed countries, and female gender is likely linked to higher mortality in low-income countries. In Australia, there are an average of 13 flood-related unintentional drowning deaths annually, with an annual average of three flood-related drowning deaths among children and adolescents 0–19 years of age. Slow onset flooding is most common, accounting for over half (56%) of all drowning fatalities; flash flooding is responsible for a further 27% of deaths. Males are overrepresented in statistics; however, females are at higher risk of flood-related drowning than non-flood related drowning.

All drownings are preventable, and studies has identified key causal factors that must be considered in advocacy and prevention efforts. These include: the importance of adult supervision, avoiding flooded waterways when driving or for recreational purposes, and the increased risks for those residing in geographically isolated and socially disadvantaged areas. Findings must be considered when developing interventions and advocacy for the purposes of the reduction of child and adolescent drowning during times of flood. Seven people have died and thousands were evacuated as Penang was inundated by up to 4 meter of water after an 18-hour storm. The state's worst flooding caused its Chief Minister to enlist Malaysia's police and military to help with relief efforts.

16.2.2 Communicable diseases

Various health consequences gave been reported to be associated with flooding and rainfall. Among the communicable diseases commonly associated with flooding and rainfall are cholera, acute gastro enteritis, typhoid, hepatitis A, dengue fever and leptospirosis.

Flood water contains various dangerous pollutants including pesticides, toxins and pathogens. These contaminants may harm one’s health in the form of airborne dust, when the flood water recedes later and dried sediments were disturbed during the cleansing process. The community exposed to flood water may experience viral respiratory infections. Damp indoor conditions may also cause certain diseases such as aspergillosis.

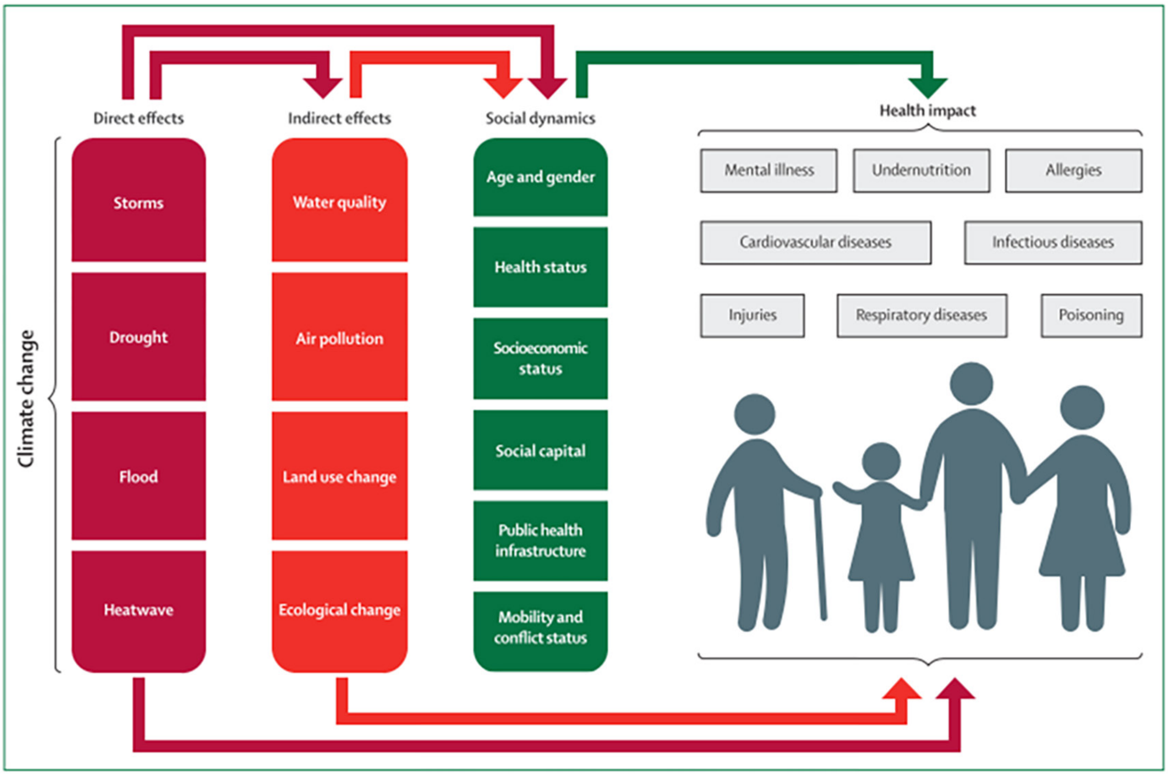

Figure 31: Health impacts of climate change. Source: Watts et al. (2015)[66].

a) Leptospirosis

Leptospires are organisms found in animals including cattle, pigs, horses, and dogs can become infected, in addition to many wildlife species such as rodents, white-tailed deer, raccoons, foxes, skunks, and sea lions. Leptospirosis is one of the most common transmissible infections from animals to human. The

66 Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W. & Costello, A. (2015). Health and climate change: policy. *The Lancet* 6736(15).

interaction between humans, animals, and bacteria in the environment can be enhanced during flooding, leading to outbreaks and epidemics in areas where the infection is already endemic. Literature stated that the organisms can survive in water and soil up to several weeks. Exposure to contaminated environments where Leptospira thrive increases the risk of contracting the disease and pose a greater risk of infection through cuts on the skin during heavy rain and flooding. Working or living in flooded areas also has been identified as a risk factor for increased leptospirosis contraction. The total number of cases is mostly affected by the transmission rate of Leptospira to humans are those in flooded areas. It is, therefore, best to avoid flooded areas to reduce the risk of an outbreak of Leptospirosis. Moreover, protective equipment, such as boots and gloves, are recommended when in contact with flood water. Flooding is an important risk factor for the disease in Argentina, Brazil, Thailand and Malaysia[67].

In Malaysia, from the demographic characteristics of the disease victims, more younger males were disproportionately affected. Living in densely populated areas in close proximity to water bodies and garbage accumulation contributed to the increased exposure, thus, leading to infection. The incidence of leptospirosis was found to increase 2–3 weeks after heavy rainfall and flooding indicating the incubation period of the disease[68]. The ongoing climate change can lead to more frequent extreme weather events, especially flooding, in Malaysia. From this study, spatial mapping of hotspots and clustering analysis of leptospirosis outbreaks also offer aid in improved visualisation of areas that require more assistance in environmental health management and services post flooding to help reduce the health impacts. The mapping showed the areas with incidence of leptospirosis when compared to the pre- and post-flood periods. This serves as an early indication for future preparedness and allocation of public health interventions in areas affected by flooding.

By looking at the possible climatic factors that may influence outbreaks, we can determine the disease outbreak patterns and help in future predictions of outbreaks after flooding. This, together with improved disease surveillance may enhance our preparation of future disaster and reduce the incidence and outbreaks of the disease. In summary, understanding the spatial distribution and associated factors of leptospirosis can help improve future disease outbreak management after floods.

16.2.3 Non-communicable diseases

a) Mental health

While most people who are involved in disasters recover with the support from their families, friends and colleagues, the effects on some people's health, relationships and welfare can be extensive and sustained. Flooding can pose substantial social and mental health problems that may continue over extended periods of time. Flooding can challenge the psychosocial resilience of the hardiest of people who are affected[69].

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67 Baharom, M., Ahmad, N., Hod, R., Jaafar, M.H., Arsad, F.S., Tangang, F. et al. (2024). Environmental and occupational factors associated with leptospirosis: A systematic review. *Heliyon* 10(e23473): 1-15.

68 Mohd Radi, M.F., Jamal, H.H., Jaafar, M.H., Hod, R., Ahmad, N., Nawi, M.A. et al. (2018). Leptospirosis outbreak after the 2014 major flooding event in Kelantan, Malaysia: A spatial-temporal analysis. *American Journal of Tropical Medicine & Hygiene* 98(5): 1281-1295.

69 Irniza R., Emilia Z.A., Sharifah Norkhadijah S.I., Vivien H., S.M. Praveena, Karmegam K., Yu Bin H., Nik Nurul Aizzah NA, Syukriah MH, Suriani I. and Zailina H (2016). The Association Between KAP on Disasters with Depression, GAD and PTSD Among Flood Victims. *Indian Journal of Environmental Protection.36 (11): 888-894*.

The Health Protection Agency (HPA) undertook a review of the literature published from 2004 to 2010[70]. It is intended to assess and appraise the epidemiological evidence on flooding and mental health; assess the existing guidance on emergency planning for the impacts of flooding on psychosocial and mental health needs; provide a detailed report for policymakers and services on practical methods to reduce the impacts of flooding on the mental health of affected people; and identify where research can support future evidence-based guidance.

The review indicates that flooding affects people of all ages, can exacerbate or provoke mental health problems, and highlights the importance of secondary stressors in prolonging the psychosocial impacts of flooding. The distressing experiences that the majority of people experience, whether transiently or for longer periods after disasters, can be difficult to distinguish from symptoms of common mental disorders. This emphasises the need to reduce the impact of primary and secondary stressors on people affected by the flooding and the importance of narrative approaches to differentiate distress from mental disorders. Much of the literature focuses on post-traumatic stress disorder; diagnosable depressive and anxiety disorders and substance misuse are under-represented in the published data. Most people's psychosocial needs are met through their close relationships with their families, friends and communities; smaller proportions of people are likely to require specialised mental healthcare. Finally, there are a number of methodological challenges that arise when conducting research and when analysing and comparing data on the psychosocial and mental health impacts of floods.

The HPA's findings showed that a multi-sector approach that involves communities as well as agencies is the best way to promote wellbeing and recovery. Agreeing and using internationally understood definitions of and the thresholds that separate distress, mental health and mental ill health would improve the process of assessing, analysing and comparing research findings. Further research is needed on the longitudinal effects of flooding on people's mental health, the effects of successive flooding on populations, and the effects of flooding on the mental health of children, young people and older people and people who respond to the needs of other persons in the aftermath of disasters.

The studies analysed in the report are clear that flooding is very stressful and that the stress continues for a long time after the water has receded. Flooding affects people of all ages, and it can herald bereavement; economic problems for families; behavioural problems in children; increased substance use and/ or misuse; increased domestic violence; as well as exacerbating, precipitating or provoking people's existing problems with their mental health.

Often, people's experiences, which reflect the personal and social meanings of the event for them, and the understandings and meanings they derive from it, have more influence on the psychosocial impact of the event than the event itself. Recovery from distress after disasters, including flooding, is characterised by adaptation to circumstances that have changed and by rebuilding communities.

Many people experience distress that may be relatively transient after any disaster and being distressed temporarily is not antithetical to people also

[70] Health Protection Agency December (2011). *The Effects of Flooding on Mental Health. Extreme Events and Health Protection.* Centre for Radiation, Chemical and Environmental Hazards. Health Protection Agency, 151 Buckingham Palace Road, London.

being resilient. Furthermore, the wider literature shows that the experiences of people who are distressed in the aftermath of all disasters including floods, are not always easy to distinguish from the symptoms of common mental disorders. On the other hand, the research suggests that the incidence and prevalence of common mental disorders after flooding are substantially increased and that these disorders can persist long after the flooding has passed. This stresses the importance of planning for and providing effective and timely public mental health and clinical responses.

The threshold between what might be considered a common or anticipated response to an extreme event and what is indicative of a person developing a disorder are difficult to define. Many turns on the severity, duration, impacts of these experiences on people's lives, and, particularly, the trajectory of their reactions over time, and the severity and persistence of any dysfunction they accrue, when it comes to differentiating distress and disorder. The authors found that the focus in the literature is on post-traumatic stress disorder (PTSD). While that is valuable, it is also accompanied by a relative neglect of the crucial wider background morbidity that is found in all populations, including after disasters. For example, depression is a diagnosis that is under-represented in the published data. However, a consistent finding across many studies is that people's level of exposure to the event and their earlier exposures to other traumatic experiences are strongly associated with PTSD.

When looking at PTSD, findings reveal that the symptoms may not decline over time as quickly as was thought previously. Social cohesion has a significant effect on susceptibility to symptoms of PTSD and it, therefore, must be considered when developing public health strategies[71].

People who develop mental disorders, risk factors and co-variants did not a have a constant association with poorer mental health across all the studies, partly due to methodological differences and partly because of the unique characteristics of each flood. However, as in general population studies, levels of exposure to the event(s), gender, age, and socio-economic status were generally associated with mental ill health.

There is a lack of studies which have investigated the impact of flooding on the mental health of children, young people and older people. There are, however, indications that both children and older people suffer PTSD after flooding and that the prevalent figures may well be greater than those that are found for adults of working age. Children, young people and older people may be more vulnerable than are adults of working age because they are dependent on adults' responses to the floods that affect families. The parents' wellbeing, for example, affect the quality of their parenting; people's direct experiences and those that affect their carers may, separately and in interaction, either protect them or intensify the negative effects on children and older people.

16.3 Health impacts of sea level rise

The projected range of maximum sea level rise along the coastlines of Malaysia at 21 selected tidal stations for current timeline (2022), by 2050, and by 2100, with respect to sea level in 2015 as a baseline, is shown in Figure 32 (previously shown as Table 27). The Malaysian coastline was projected to experience a maximum SLR of 0.22-0.25 m by 2050 and 0.67-0.74 m by 2100. SLR of up to 0.25 m and 0.74 m are expected at the Kudat coastline by 2050 and

[71] Jessica Elizabeth Lamond, Rotimi D. Joseph, David G. Proverbs (2015). An exploration of factors affecting the long-term psychological impact and deterioration of mental health in flooded households. *Environmental Research. 140: 325–334*.

2100, respectively. Sarawak coastlines could face SLR of 0.24 m by 2050 and 0.71-0.72 m by 2100. In Peninsular Malaysia, the west coast (with a projected rise of 0.22-0.23 m by 2050 and 0.67-0.69 m by 2100) was projected to face a lower SLR than the east coast (0.23 m by 2050 and 0.70-0.71 m by 2100).

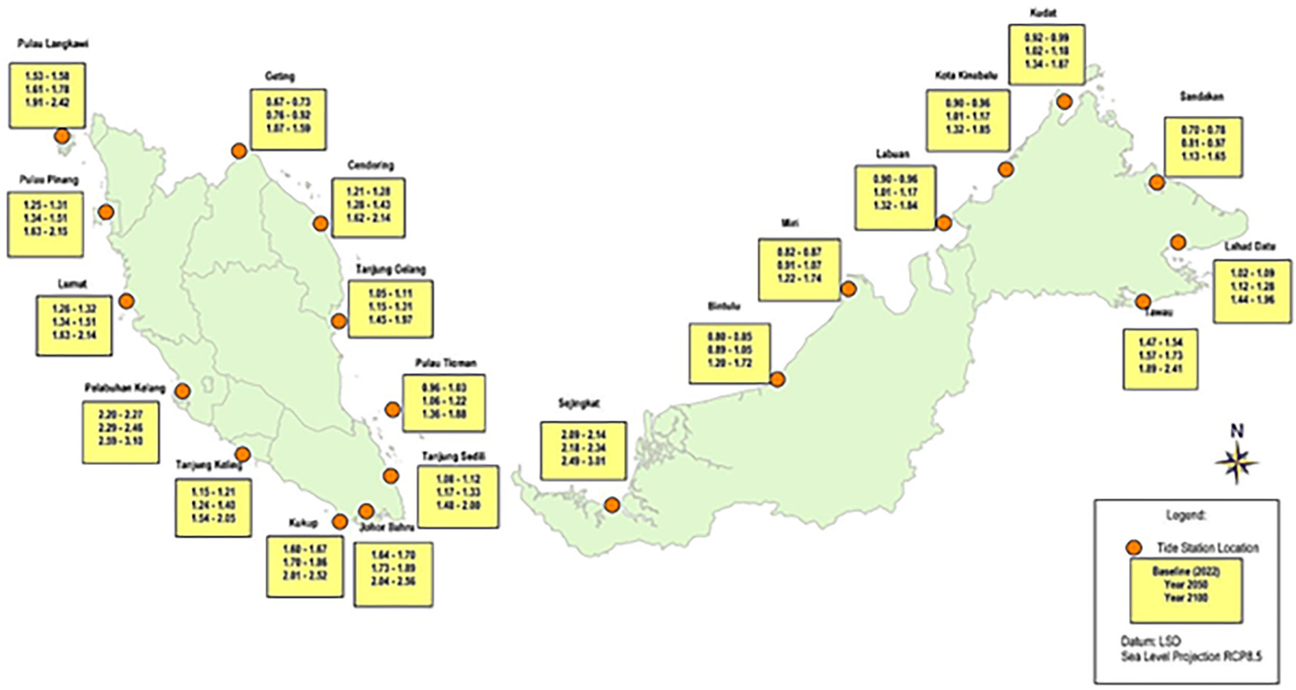

Figure 32 (previously shown as Figure 27): Projected range of sea level values (metres –with added sea level rise value from MSL) at selected tidal stations under the current timeline, 2050 and 2100.
Source: NAHRIM (2023)[43].

What is obvious as a direct impact of sea level rise from climate change is that it will undoubtedly inundate low lying islands and coastal areas. However, it would also increase salinity in coastal zones. Rising sea levels increase the salinity of ground water and pushes salt water further upstream. Higher salinity can make water undrinkable without desalination and harms many aquatic plants and animals[69]. The following are potential health impacts from sea level rise:

16.3.1 Coastal flooding and population migration

Coastal flooding will result in the loss of beach and sea-fronting lands, resulting in population migrations and relocations from the coastal areas. This may include private individual properties and private hospitality industry properties such as resorts and hotels. This would most likely be experienced in Sabah on its eastern and south-eastern coasts around Kudat, Sandakan and Tawau. The rest of East and West Malaysia are unlikely to be severely affected by significant sea level rise.

While there is increasing focus on population adaptation to climate-related migrations, the health impacts of planned relocations and forced displacement have not been thoroughly examined. According to the Intergovernmental Panel on Climate Change (IPCC), migrations are and will increasingly be influenced by climate change and environmental degradation, and that it needs to be addressed in a focused and coordinated manner[70].

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69 Moser S.C., Davidson M.A., Kirshen P., Mulvaney P., Murley J.F., Neumann J.E., Petes L. & Reed D. (2014). Ch. 25: Coastal Zone Development and Ecosystems. Climate Change Impacts in the United States: The Third National Climate Assessment. In: J.M. Melillo, Terese T.C. Richmond, and G.W. Yohe (Eds.), U.S. Global Change Research Program, 579-618.

70 Schwerdtle, P., Bowen, K. & McMichael, C. (2018). The health impacts of climate-related migration. *BMC Medicine* 16:1.

Health impacts of population relocations can be far reaching as it disrupts family roles and functions. Figure 32 shows a conceptual framework of human exposure to climate and environmental changes as a driver of population migrations and its potential impacts on human health. Health impacts are related to population immobility or trapped populations and population mobility due to displacement or relocation. Among the potential health impacts are psychosocial health, infectious diseases, inadequate water supply and sanitation, food insecurity, and exposure to environmental risks at both the original and destination sites[66].

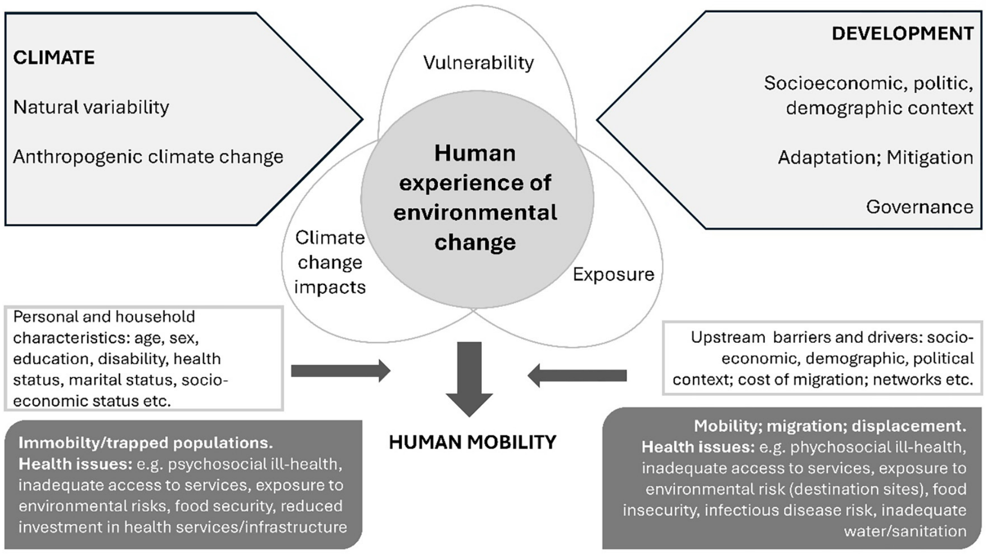

Figure 33: A conceptual framework showing the human experience of environmental changes as a driver to migration and its potential impacts on health.

16.3.2 Impacts on agriculture and nutrition

Many coastal areas and river deltas are rich agricultural lands, for example, the Mekong Delta. Sea level rise will result in saltwater intrusion and increased salinity of the soil and ground water of these coastal areas. Although we do not have large river deltas in Malaysia, many coastal areas in Kedah and Perlis are rich paddy lands.

Saltwater intrusion which can be facilitated by natural conditions, human activities or climate change, is a big threat to mankind from the socioeconomic, environmental and ecological perspectives. Agriculture, which is normally the largest consumer of water, is both a contributor and also the most vulnerable sectors to saltwater intrusion, especially in coastal low-lying areas. With the increasing demands and competition of water use owing to economic booms, population growth and climate fluctuations, sustainable water resource management is critical in overcoming this issue[71].

Saltwater intrusion into coastal areas may affect food and cash crop production in these areas. A study in Lebanon showed that the yield from a banana crop grown on low salinity plots was 25% higher than that grown on high salinity plots[72]. For coastal areas inhabited by poor communities which rely heavily on agriculture for food and cash crops for income, this may plunge them into poverty and malnutrition, especially among children.

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[71] Duan Y. (2016). Saltwater intrusion and agriculture: a comparative study between the Netherlands and China. Stockholm: KTH Royal Institute of Technology, School of Architecture and the Built Environment.

[72] El-Fadel, M., Deeb T., Alameddine I., Zurayk R. & Chaaban J. (2018). Impact of groundwater salinity on agricultural productivity with climate change implications. *International Journal of Sustainable Development and Planning* 13(3): 445-456.

16.3.3 Saltwater intrusion and malaria

Rising sea levels may act synergistically with global climate change to increase the transmission of mosquito-borne diseases in coastal zones. An expansion of brackish water bodies in coastal zones can increase the densities of salinity tolerant mosquitoes like *Anopheles sundaicus* and *Culex sitiens*, and also leading to the adaptation of freshwater mosquito vectors like *Anopheles culicifacies*, *Anopheles stephensi*, *Aedes aegypti*, and *Aedes albopictus* to salinity[73].

Increased salinity in coastal areas may lead to the propagation of certain disease vectors. One such species is *Anopheles sundaicus*, a coastal vector for malaria found along coastal regions with high salinity. *Anopheles sundaicus* is a dominant malaria vector in the coastal areas of Indonesia. It is also still one of the most important vector-borne diseases in Malaysia, primarily in Sabah and Sarawak, despite showing reduction of cases for a decade. It breeds in brackish water[74]. Therefore, increased salinity in coastal areas due to saltwater intrusion will turn these areas into excellent breeding grounds for this mosquito vector species, which will in turn increase the incidence of malaria along coastal areas where *An. Sundaicus* can be found.

16.4 Health impacts of extreme weather events

16.4.1 Health impacts of monsoon flood

Monsoon flood is a recurrent phenomenon in Malaysia. It commonly occurs during the Northeast Monsoon period each year (November to February) and the most affected states are Kelantan, Terengganu Pahang, Johor, Sabah and Sarawak. However, the Northeast Monsoon floods also hit other states, but with normally lesser intensity. The health impacts due to monsoon floods varies each year and are very much related to the scale and intensity of the floods. Due to climate change and climate phenomenon such as La Nina, variability in the climate pattern has resulted in unpredictable patterns of floods, variations in frequency, severity and scale of affected areas.

One of the worst ever recorded monsoon floods that hit Malaysia was in 2014/2015 (December 2014-January 2015). The impacts were widespread; including the disruption o public health services, environmental and sanitation services were affected, injuries, drowning, communicable diseases, mental health and chronic diseases. The mind map in Figure 33 summarised the health impacts of monsoon floods.

16.4.2 Health impacts of El Nino

A changing climate is expected to increase average ambient temperatures and the frequency and intensity of hot days. Furthermore, the intensity of hot weather is expected to worsen during the climate phenomenon called El Nino. Heat waves increase the risk of health-related illness especially among vulnerable group such as people with chronic diseases, the elderly and children. Many publications related to heatwave and health consequences were from Western countries. For instances, the 2003 heat-wave in Europe it was estimated to cause 14,802 excess deaths in France (National Institute of Public Health Surveillance, 2003), 2,045 excess deaths in the United Kingdom, and 2,099 in Portugal. Malaysia has also experienced a few episodes of heat waves in the past but there were no publications documenting the impact except the heat wave episode in 2016. During the 2016 heatwave episode, there were 200 heat-related illness cases reported to the Ministry of Health in which 22 cases were heatstroke cases, 126 heat exhaustion cases, and 52 heat cramps.

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73 Ramasamy, R. & Surendran, S.N. (2012). Global climate change and its potential impact on disease transmission by salinity-tolerant mosquito vectors in coastal zones. *Frontiers in Physiology* 3: 1-14.

74 Abdul Rahim F.A., Abdul Mutalip M.H., Hasim M.H., Fikri Mahmud M.A. & Yeop N. (2019). Factors associated with distribution of *Anopheles sundaicus* in coastal area, Kuala Penyu, Sabah. I*nternational Journal of Academic Research and Development* 4(4): 10-16.

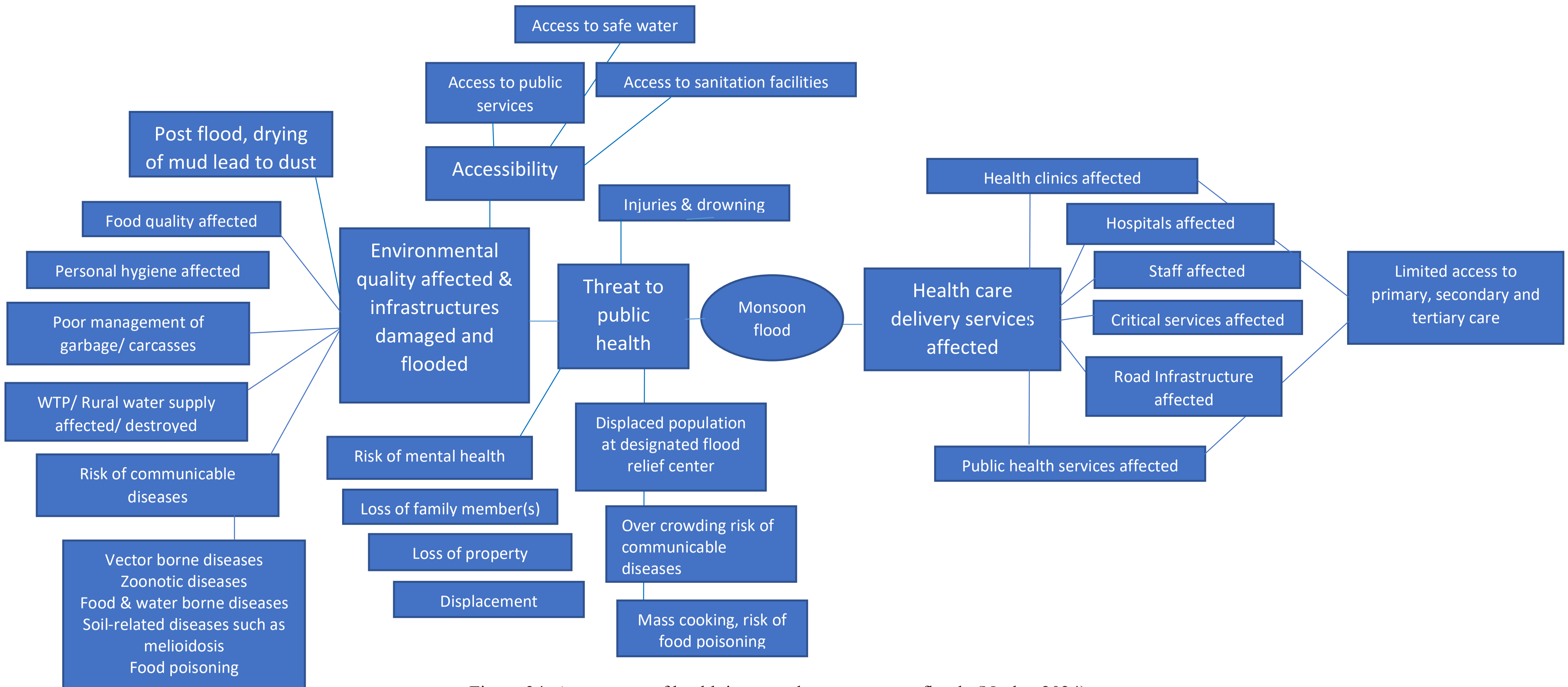

Figure 34: A summary of health impacts due to monsoon floods (Norlen 2024).

Heat related illness varies from least severe to fatal heat strokes. Vulnerability to heat depends on climate factors (such as the frequency of heatwaves) and on individual risk factors, including medical, behavioural and environmental factors. Kilbourne (1992, 1999) has identified as predictives for heat stroke and heat-related death and illnesses:

- being elderly.
- impaired cognition, such as dementia.
- pre-existing disease(s).
- use of certain medications.
- level of hydration.
- housing (such as living in a certain building type or on a higher floor).
- the presence and use of air-conditioning in the home or residential institution.

With climate change, more transboundary haze is expected as a result of more intense droughts and higher possibility of forest fires in the region. Indeed, Malaysia had experienced many episodes of poor air quality due to transboundary haze because of forest fires in the region. Air quality is strongly related to the availability of source of pollutants, dilution, dispersion, transport, and deposition of the pollutants that are influenced by meteorological variables such as wind speed and direction, ambient temperature, humidity and rainfall.

Therefore, air quality is sensitive to climate change. Biomass burning or bushfire is one of the most significant contributors that determine the trend and status of air quality which is worsened by climate change. The first episode of poor air quality in Malaysia was associated with the haze of April 1983, which caused severe disruptions to daily life. Since then, the haze has recurred almost every year, in particular during south-westerly (June to September) and north-easterly (December to March) monsoons with major prolonged episodes recorded in 1991, 1992, 1997, 2003, 2005, 2013[75] and a more recent episode occurred in 2015. Historically, more severe haze episodes occurred during severe El Nino years.

In Malaysia, a few studies have been conducted to document the effects of poor air quality on health related to forest fires or biomass burning. For example, during the 1997 haze, a substantial increase in cases of upper respiratory tract infections, conjunctivitis, and asthma had been recorded and associated with short-term exposure to a predominant pollutant, PM10[76,77]. A list of studies conducted are listed in Table 9.

Table 9. Air pollution studies in Malaysia related to biomass burning/forest fires.

Authors	Study Objectives	Findings
Hashim, J., Hashim, Z., Jalaludin, J., Lubis, S. & Hashim, R. (1998).	The aim of the study was to examine impact of haze on children's respiratory functions.	The study found statistically significant decreases of lung functions in these children measured between the non-haze period a year earlier and the haze period in 1997.

75 Sahani, M., Zainon, N.A., Mahiyuddin, W.R.W., Latif, M.T., Hod, R., Khan, M.F., Mohd Tahir, N., Chan, C-C. (2014). A case-crossover analysis of forest fire haze events and mortality in Malaysia, *Atmospheric Environment* 96: 257-265.

76 Awang, M.B., Jaafar, A.B., Abdullah, A.M., Ismail, M.B., Hassan, M.N., Abdullah, R., Johan, S. & Noor, H. (2000). Air quality in Malaysia: Impacts, management issues and future challenges. *Respirology* 5: 183-196.

77 Brauer, M. & Hisham-Hashim, J. (1998). Peer reviewed: fires in Indonesia: crisis and reaction. *Environmental Science & Technology* 32(17): 404A–407A.

Authors	Study Objectives	Findings
Awang, M.B., Jaafar, A.B., Abdullah, A.M., Ismail, M.B., Hassan, M.N., Abdullah, R., Johan, S. & Noor, H. (2000).	The study used a matched control group to compare the pulmonary functions of 16-year-old schoolchildren exposed to different levels of PM10 (i.e., 103 µg/m3 vs. 47 µg/m3 in the control group).	The study found significant reduction in spirometry parameters among those with higher long-term exposure to PM10.
Wan Mahiyuddin, W.R., Sahani, M., Aripin, R., Latif, M.T., Thach, T.-Q. & Wong, C.M. (2013).	This aims to estimate the short-term health effects of pollutants on mortality in Klang Valley over a 7-year period, 2000-2006 using a time series method. The study was based on mortality statistics from the national database, which captured all mortality cases in the population. Data for PM10, SO2, NO2, O3, CO and meteorological conditions were obtained from the Malaysian Department of Environment.	The study found statistically significant effects of PM10 at lag 1 (RR = 1.0099, 95% confidence interval [CI] = 1.009–1.0192) and 5-day cumulative effect of O3 (RR = 1.0215, 95% CI = 1.0013–1.0202).
Othman, J., Sahani, M., Mahmud M. & Sheikh Ahmad M.K. (2014).	The study assessed the economic value of health impacts of transboundary smoke haze pollution in Kuala Lumpur and adjacent areas in the state of Selangor. Daily inpatient data from 2005, 2006, 2006, and 2009 were collected from four hospitals. On average there were 19 hazy days.	A smoke haze occurrence was associated with an increase in patient cases by 2.4 per 10,000 populations each year, representing an increase of 31 percent from normal days.
Sahani, M., Zainon, N.A., Wan Mahiyuddin, W.R., Latif, M.T., Hod, R., Khan, M.F., Tahir, N.M. & Chan, C.C. (2014).	The aims of the study were to examine the risk of haze days due to biomass burning on daily mortality in the Klang Valley region between 2000 to 2007. A case-crossover study design was used to model the effects of haze based on PM10 concentration to the daily mortality. The time-stratified control sampling approach was used, adjusted for PM10 concentration, time trend and meteorological influences.	The study reported significant 2-day delayed effects of haze events on all-cause mortality among children less than 14 years of age (odds ratio [OR] = 1.41, 95% CI = 1.01–1.99). Effects of haze events on respiratory mortality were immediate (i.e., current-day, lag 0) (OR = 1.19, 95% CI = 1.02–1.40). This immediate effect on respiratory mortality was particularly discernible among elderly males over 60 years old (OR = 1.41, 95% CI = 1.09–1.84).

16.5 Drinking water supply (quality & quantity)

In Malaysia, a total of 98% of drinking water supply originates from surface water that is treated and supplied as tap water, while only 2% of the total water supply is from groundwater. Like other developing countries, surface water degradation in Malaysia is linked to climate change, increased urbanisation rate, population growth, along with domestic, commercial, and agricultural activities[78]. Potable water begins as raw water drawn from the surface and processed through a series of purification steps in a drinking water treatment plant. The majority of drinking water treatment plants use conventional drinking water treatment systems, with only a few having advanced technology, such as Actiflo Clarification System and Dissolved Air Floatation. There are a few Malaysian states (e.g., Kelantan, Terengganu, Kedah, Sabah) wherein groundwater is utilised for drinking water and public water supply due to location remoteness, low population density, difficult terrain and poor infrastructure access.

[78] Camara, M., Jamil, N.R. & Abdullah, A.F. (2019). Impact of land uses on water quality in Malaysia: a review. *Ecological Processes* 8(1).

Overall, tap water quality in Malaysia has been found to be acceptable for 97.62% of the population, primarily in urban areas, which have access to treated water . The quality of drinking water in Malaysia is based on the National Standard for Drinking Water Quality published by the Ministry of Health.

17. Recommendations for Prevention of Health Effects and Adaptation

17.1 Vulnerabilities of health facilities

Malaysia had experienced 51 natural disaster events in the last two decades (1998-August 2018) where 281 people have died with over 3 million people affected, and these disasters caused nearly US$2 billion (MYR8 billion) in damages. Malaysia is susceptible to hazards including flooding, landslides, droughts, and forest fires[47]. Hence, health facilities too, are at risk of these hazards.

The health facilities included both the public and private sectors where there are fewer hospitals and clinics compared to the private sector, but the public sector has more hospital beds in total, as shown in Table 10. Public hospitals included five army hospitals and five university hospitals, while the rest were MOH hospitals[60].

Table 10. Distribution of key healthcare resources by sector, 2019.

	Public	Private
Hospitals	145	208
Hospital beds	42 183	16 469
Clinics	1 114	7 988

Previous studies on recent disasters and crisis incidents between 2015 to 2017 showed that there were hospital disasters recorded in Malaysia[80], as shown in Table 11.

Table 11. Disasters and crisis incidents affecting hospitals and healthcare facilities in Malaysia (2015 – 2017).

Disasters/crisis incidents	Year	Hospitals	
Flood	Nov 2016	Sultanah Aminah Hospital	Electricity was shut down - patients were moved to Mahmoodiah Health Clinic.
	Dec 2016	4 Health Clinic in Terengganu	All clinics had to be closed for operation until the flood was over.
	Jun 2017	Hulu Terengganu Hospital	The hospital was not accessible - staff had to be brought in using bulldozers while visitors were advised not to come to the hospital or get medical care at the nearest clinics.

79 Macrotrends. (2022). Malaysia Clean Water Access 2000-2022. Available at: https://www.macrotrends.net/countries/MYS/malaysia/clean-water-access-statistics. Accessed on: 1 December 2022.

80 Noralfishah, S., Sheikh Kamran, Abid., Umber, N., Nur Putri N.M., Siti Kursiah, K.A.L. & Haridzah, F.M.H. (2020). Need for resilience healthcare facilities management (RHFM) in Malaysia's public hospitals. A critical literature reviews. *IEOM Society International* 2336-2348.

Disasters/crisis incidents	Year	Hospitals	
	Aug 2017	Sultanah Fatimah Specialist Hospital	Flash floods affected the main entrance and car park.
	Nov 2017	Penang Hospital Sultan Abdul Halim Hospital	Transportation unit, ground floor of Block C & D was affected - 104 patients and 4 newborn infants were moved to other wards. The car parks were flooded due to flash floods.
Earthquake	Jun 2015	Ranau Hospital & clinics	The hospital and 9 clinics in Ranau, Tuaran & Papar were badly affected - cracks on walls, stairs and pillars.
Fire/Smoke	July 2016	Lundu Hospital Sabah KPJ Specialist Hospital	Short circuit was the source of fire. Main switch room was on fire.
	Aug 2016	Sri Kota Specialist Medical Centre	Stores in Level 9 were affected.
	Oct 2016	Sultanah Aminah Hospital	A fire in the ICU ward causes 6 patients to die andanother fire occurred in an operation theatre the day after.
	Jan 2017	Tanjung Rambutan Mental Hospital	A store and ceiling in ward 11 were on fire - 21 residents were evacuated to another ward.
	Feb 2017	Shah Alam Hospital	Small fire occurred in the NICU ward - all patients and infants were evacuated to the nearest ward.
	March 2017	Segamat Hospital	The linen room in men's ward was on fire - all patients including patients from the women's ward next to it were moved to the lobby.
	May 2017	Canselor Tunku Mukhriz Hospital	Fire occurred in the office equipment store in Level 3, Clinical Block.
	July 2017	Tanjung Karang Hospital	Fire caused by fan in ward 2 - all patients were moved, and the entire block was evacuated.
	Nov 2017	Sibu Hospital	Smoke was detected coming out of ward 23's ceiling - 1000 patients, staff and visitors in ward 18 were moved.

From this literature review on all hospital disasters that had occurred in Malaysia, there were three main issues that were the root causes, namely climate change, old hospital buildings and poor practices in facility management (FM) in hospitals[78].

17.2 Prevention of heat related illnesses

Timely risk communication to community to modify the behaviour of individuals and to increase awareness of the dangers connected with heat exposure in order to reduce heat-related impact. Hence risk communication needs to be linked to specific advice on how people recognise the problem and what they should do to protect themselves and others. A public health response plan is needed to ensure a timely risk communication being delivered during heat waves.

An efficient heatwave warning system to alert the agencies and the public is needed (the role of MMD to related agencies, take the European system, for example). This is very important for a timely response by public and agencies during heat waves. An effort is also needed to educate the public regarding the functions and the importance of a heatwave warning system.

A National heatwave action plan or hot weather action plan is needed to guide the agencies during extreme events. Inter-agency coordination is very important to provide places equipped with air conditioning for people to cool down and take shelter during extreme heat waves. A long-term plan is needed to reduce the ambient temperature especially in urban areas because of the heat island effect. Promoting green buildings, landscaping in the cities and planting more trees are very important long-term measures to reduce the ambient temperature. Beside a cooling effect, landscaping and trees in the city are associated with many positive impacts on physical and mental health.

17.3 Prevention of vector-borne diseases

Prevention of vector-borne diseases as a consequence of temperature rise- Dengue is a notifiable disease under the Section 10(c) Act 342 The Prevention and Control of Infectious Diseases Act 1988 in Malaysia. Strengthening the dengue surveillance systems through UNITEDengue, a network of cross-border sharing of dengue information under the Asia Pacific Dengue partnership. Structured early warning and surveillance systems for emergency preparedness, Dengue Virus Surveillance Systems such as the real time smart web-based systems called e-Dengue, e-nNotification, e-VEKPRO, i-Dengue, dengue outbreak management system (SPWD) were established with the National Dengue Surveillance Program (NDSP) Years 2009-2013. The updated NDSP (2015-2020) emphasised on the strategies to strengthen the preparedness and response capacity in order to detect cases and outbreaks for prompt action, such as the destruction of breeding areas with interagency collaboration and community participation.

17.4 Prevention of health impacts from flooding

Resilient, proactive health systems that anticipate needs and challenges are more likely to respond effectively during emergencies, save lives and alleviate human suffering. Floods are the most common natural disaster in the European Region, which has experienced in recent years some of the largest flooding events in its history. The effects of flooding on health are extensive and significant, ranging from mortality and injuries resulting from trauma and drowning to infectious diseases and mental health problems (acute and long-term). While some of these outcomes are relatively easy to track, ascertainment of the human impact of floods in Europe is still weak. The WHO Regional Office for Europe and the United Kingdom HPA collaborated to assess the health effects of floods, as well as to identify measures to prevent or minimise their health effects. The result is this document, which is intended to provide decision-makers with evidence for action before, during and after flooding events[82].

Floods have significant health impacts:

- Two thirds of deaths associated with flooding are from drowning, and the other third are from physical trauma, heart attacks, electrocution, carbon monoxide (CO) poisoning and fire. Often, only immediate traumatic deaths from flooding are recorded.
- Morbidity associated with floods is usually due to injuries, infections, chemical hazards and mental health effects (acute as well as delayed). The longer-term health effects associated with a flood are less easily identified. They include effects due to displacement, destruction of homes, delayed recovery and water shortages.
- The most common health-relevant occurrences during floods reported by European Member States are shortages of safe water, injuries and disruption of access to health services. Outbreaks of infectious diseases are rare.
- Known risk factors for flood-related mortality and morbidity are fast-flowing water, hidden hazards, water of unknown depth, driving and walking through floodwater, flood-water contamination (by chemicals, sewage and residual mud),
- exposure to electrical hazards during recovery and cleaning, unsafe drinking-water and food shortages and contamination, incomplete routine hygiene, CO poisoning, and lack of access to health services.
- Flooding of health facilities results in interruption of business, loss of infrastructure, such as water supply and electrical power, increased patient admissions and increased difficulty in providing routine medical and nursing care for patients with chronic diseases, such as diabetes, renal failure, cystic fibrosis, cancer and mental illness.

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[82] World Health Organization (2020). Floods: How to protect your health. Regional Office for Europe. Geneva, Switzerland.

- Population vulnerability to the health effects of flooding is due to a complex interaction of a variety of factors: the severity and rapidity of the flooding, health status and necessity of regular treatment, access and availability of warning, rapidity of response measures and being located in high-risk areas and high-risk built environments.

Adequate planning is vital in order to effectively minimise health effects from floods:

- The most important measure to minimise health impacts from floods is implementation of a wide, multi-sectoral all-hazards approach to emergency preparedness, translated into a local plan that includes public health and primary care.
- Adequate land use is important in reducing health effects from floods. For instance, the building of health care facilities in a flood-plain should be avoided.
- Early warning systems are important components of flood emergency plans, allowing adequate time for preparation and response.
- Provisions should be made to ensure water quality, sanitation, hygiene and food safety after the flood; health precautions during clean-up activities; protective measures against communicable diseases and chemical hazards; and measures to track and ensure mental health and well-being.
- In addition to the core elements, emergency planning should be comprehensive, taking into account gender considerations, recommendations on evacuations and displacement and the health protection of vulnerable groups.
- Surveillance for mortality and morbidity during and after the event is important, in order to obtain timely information for any interventions required.
- Further work is needed to integrate health into emergency flood plans. Whereas health is often not considered explicitly in emergency plans, flood–health prevention requires an adequate coordination of health authorities with emergency response agencies.
- Very often, only short-term health effects of floods are considered in emergency plans. However, several outcomes (including long-term mental health problems) have longer latency periods and need to be monitored and acted upon in the longer term. A multi-sectoral approach is required to prevent flood health effects. A range of primary, secondary and tertiary prevention measures can be adopted to minimise the health impact of flooding events.
- Primary prevention can be either structural (physically engineered interventions) or non-structural (policy and organisation). Examples of primary prevention include emergency plans and other methods to reduce the effects of floods, like land use management; tree planting; control of water sources and flow, including drainage systems; flood defences and barriers; design and architectural strategies; and flood insurance. These measures are normally planned far in advance.
- Secondary prevention includes identification of vulnerable or high-risk populations before floods occur, early warning systems, evacuation plans including communication and information strategies, and planned refuge areas. Secondary prevention measures for flood risk management can be taken either just before or during a flood to mitigate the health effects of the flood. Multi-sectoral collaboration is required between health services, early warning systems, water supply companies and emergency services for evacuation. Secondary prevention measures for vulnerable populations should account for difficulties in communication and mobility and the needs of people with chronic diseases.
- Tertiary measures include moving belongings to safe areas, ensuring the provision of clean drinking-water, surveillance and monitoring of health impacts, treating ill people to reduce the health impacts of flooding, and recovery and rehabilitation of flooded houses. Multi-sectoral collaboration between the military, fire department, police, water supply companies and health services are required. Robust surveillance is necessary during and after flood events to identify and control infectious disease outbreaks and non-infectious health hazards, tailor health service provision to the needs of the population, monitor

vulnerable groups and provide information for research on possible associations between flooding and ill health[83,84,85].

17.5 Prevention of health impacts from sea level rise

Sea level rise is an inevitable consequence of climate change for many of the Pacific Island nations, low lying coastal areas and river basins. Among the impacts would be coastal flooding and saltwater intrusion of surface and groundwater resources affecting coastal water supply for agricultural irrigation, aquaculture and domestic water supply. These impacts from climate change and sea level rise can have serious implications on human health of coastal and river basin communities, in term of population displacement and property damage from flooding, erosion and inundation of coastal communities, affected the potable water supply, impaired nutrition from reduced production in agriculture and aquaculture activities.

Rising sea levels amplify the threat and magnitude of storm surges in coastal areas. Water infrastructure, often located along the coast or tidally influenced water bodies, can be vulnerable to greater changes in storm surge intensity. The threat of flooding and damage to water infrastructure will continue to increase over time as sea levels rise and the magnitude of storms increase[81].

Sea level rise can also threaten the long-term operations of drinking water, wastewater and stormwater utilities. Drinking water and wastewater utilities typically remain in operation for several decades. Some facilities can be at risk of increased inundation or reduced operational capacity over the intended operating life of the facility due to sea level rise.

The most practical solution in curbing the health implications of sea level rise in coastal communities is to incorporate climate change mitigation and adaptation strategies. Among others, these would include the following[82]:

- Modelling sea-level rise and storm surge dynamics will better inform the placement and protection of critical infrastructure. Generic models have been developed to consider subsidence, global sea-level rise and storm surge effects on inundation.
- Monitoring data on sea level, precipitation, temperature, and runoff can be incorporated into flood models to improve prediction of flood and storm frequency, magnitude and severity of storm events.
- Protecting and understanding the ability of existing coastal wetlands to function as buffer to flooding and storm surges provide protection for coastal infrastructure.
- Relocating utility, health and welfare facilities and infrastructure, such as sewage and water treatment plants, hospitals, and clinics to higher elevations, would reduce risks from coastal flooding and exposure as a result of coastal erosion or wetland loss.
- Understanding and modelling groundwater conditions to inform aquifer management and projected water quantity and quality changes. Monitoring data for aquifer water level, changes in chemistry and detection of saltwater intrusion can be incorporated into models to predict future supply.

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83 Public Health England (2020).The English National Study of Flooding and Health Summary of the evidence generated to date. Public Health England, Wellington House 133-155 Waterloo Road London SE1 8UG

84 Clare E French, Thomas D Waite, Ben Armstrong, G. James Rubin, English National Study of Flooding and Health Study Group, Charles R Beck, and Isabel Oliver (2019). Impact of repeat flooding on mental health and health-related quality of life: A cross-sectional analysis of the English National Study of Flooding and Health *British Medical Journal. Open 2019;9:e031562. doi:10.1136/bmjopen-2019-031562*

85 Virginia Murray and Angie Bone (2014). Flooding and the public's health: looking beyond the short-term. *https://ukhsa.blog.gov.uk/2014/01/06/flooding-and-the-publics-health-looking-beyond-the-short-term/*

81 United States Environmental Protection Agency (USEPA). (2022). Climate adaptation and sea level rise. Available at: https://www.epa.gov/arc-x/climate-adaptation-and-sea-level-rise. Accessed on 22 April 2022.

82 Environmental Resilience Institute. (2022). Adaptation strategies for sea level rise. Indiana University. Available at: https://eri.iu.edu/erit/strategies/sea-level-rise.html#:~:text=Flood%20barriers%20to%20protect%20critical, waterproof%20containers%20or%20foundation%20systems. Accessed on 22 April 2022.

- Installing flood barriers to protect critical infrastructure such as levees, dikes, and seawalls. A related strategy is floodproofing, which involves elevating critical equipment or placing it within waterproof containers or foundation systems.
- Incorporate sea level rise into planning for new infrastructure (e.g. sewage systems).

Based on its projected future rainfall patterns, coastal topography, projected sea level rise, community communicable disease patterns, and available health facilities in affected areas, Malaysia should identify vulnerable coastal areas and communities to be targeted for mitigation and adaptation strategies, in order to help minimise the health risks of affected communities.

17.6 Prevention of health impacts from El Nino

El Niño Southern Oscillation (ENSO) is a climate event that originates in the Pacific Ocean but has wide-ranging consequences for weather around the world and is especially associated with droughts and floods (Figure 34). The irregular occurrence of El Niño and La Niña events has implications for public health. On a global scale, the human effect of natural disasters increases during El Niño. The effect of ENSO on cholera risk in Bangladesh, and malaria epidemics in parts of South Asia and South America has been well established. The strongest evidence for an association between ENSO and disease is provided by time-series analysis with data series that includes more than one event. Evidence for ENSO's effect on other mosquito-borne and rodent-borne diseases is weaker than that for malaria and cholera. Health planners are used to dealing with spatial risk concepts but have little experience with temporal risk management. ENSO and seasonal climate forecasts might offer the opportunity to target scarce resources for epidemic control and disaster preparedness.

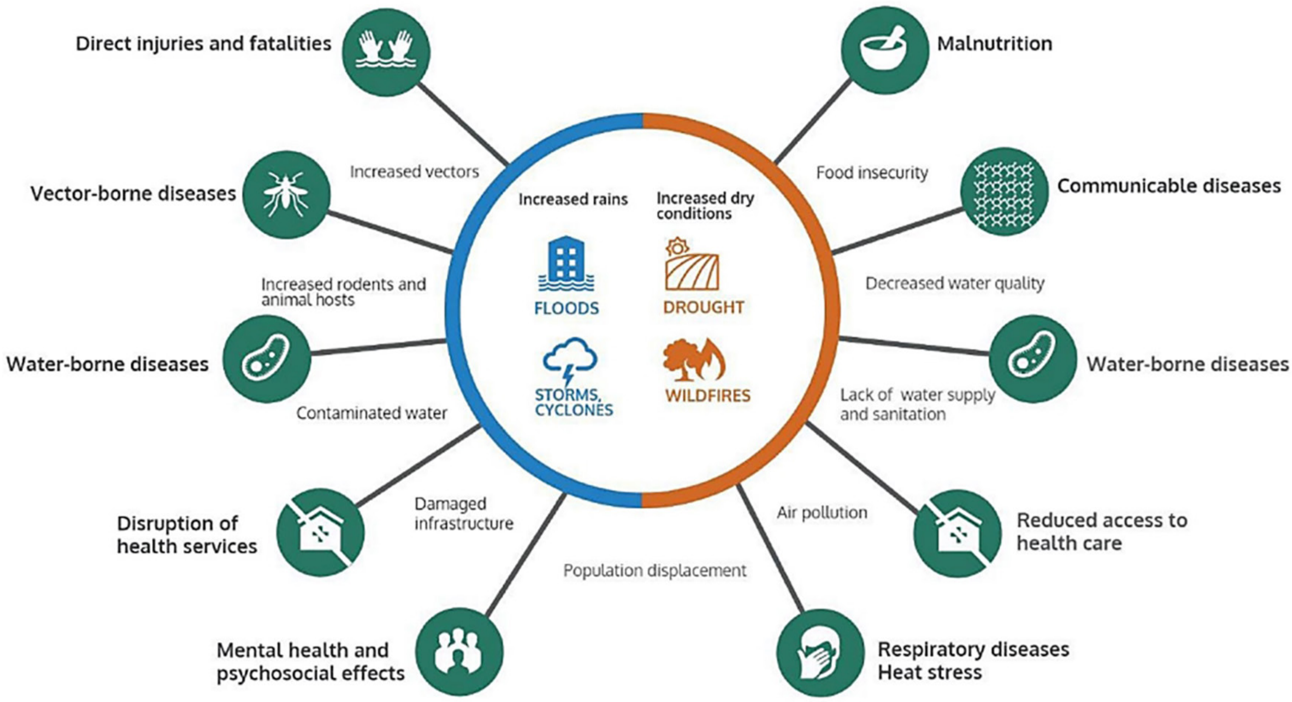

Figure 35: Health impacts from natural disasters. Source: WHO (2016)[83].

Steps to prevent and reduce the health effects of El Niño include disease surveillance; controlling the transmission of diseases (e.g. vaccinations) and the vectors that spread diseases; mobilising communities to promote health and hygiene practices; improving water and sanitation services; strengthening logistics and medical supply chains; providing emergency medical care and maintaining access to health services; and effective coordination of preparedness and response measures.

83 World Health Organization (WHO). (2016). El Niño and Health – Global Overview – January 2016. Available at: https://cdn.who.int/media/docs/default-source/climatechange/who_el_Niño_and_health_global_report_21jan2016.pdf?sfvrsn=778b05d2_4. Accessed on: 3 February 2023.

Conclusion

Climate change, driven predominantly by human activities such as the burning of fossil fuels, deforestation, and industrial processes, has resulted in significant alterations to global temperatures and weather patterns. In Malaysia, these changes manifest through increased frequency and intensity of extreme weather events, rising sea levels, and shifting rainfall patterns. These climatic changes pose severe risks to health, including heat-related illnesses, vector-borne diseases, respiratory problems due to poor air quality, and water and food insecurity. This document outlines the scientific basis of climate change, drawing on the extensive work of the Intergovernmental Panel on Climate Change (IPCC). It highlights the findings from the IPCC's Fifth and Sixth Assessment Reports, which underscore the unequivocal human influence on the climate system and the escalating risks associated with continued greenhouse gas emissions. These reports provide a critical foundation for understanding the magnitude of climate change impacts and the necessity for robust mitigation and adaptation strategies.

Malaysia's response to climate change is framed by its National Policy on Climate Change, which was approved in 2009. This policy integrates climate change responses into national development plans, emphasising sustainable development, environmental conservation, coordinated implementation, effective stakeholder participation, and adherence to international responsibilities. Institutional arrangements have been restructured to enhance governance and policy implementation, with the Ministry of Natural Resources and Environmental Sustainability (NRES) and the Malaysia Climate Change Action Council (MyCAC) playing pivotal roles. Projections indicate that Malaysia will experience significant temperature increases and changes in rainfall patterns throughout the century. These projections necessitate proactive measures to safeguard public health and the environment. Historical data on temperature trends, rainfall patterns, and sea level rise provide a crucial context for understanding current and future challenges. This document underscores the importance of international cooperation in addressing climate change, highlighting Malaysia's commitments under the United Nations Framework Convention on Climate Change (UNFCC) and the Paris Agreement. It calls for immediate and sustained actions to reduce greenhouse gas emissions, enhance resilience, and support vulnerable communities.

In conclusion, the policy statement serves as a critical roadmap for Malaysia to navigate the complex challenges posed by climate change on health. It emphasises the need for integrated and evidence-based approaches to mitigate adverse impacts, adapt to changing conditions, and promote sustainable development. The health and well-being of Malaysia's population, alongside the preservation of its rich biodiversity, depend on the swift and coordinated implementation of these policies and actions.

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