Adapting Airports in Latin America and the Caribbean to a Changing Climate

LATIN AMERICA-CARIBBEAN
AIRPORTS COUNCIL INTERNATIONAL

The **voice** of
Latin American & Caribbean
Airports

FOREWORD

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Latin America and the Caribbean depends on air transportation for its social and economic development. Particularly in the Caribbean, due to its geographical characteristics, maritime transport is the only other transportation alternative, but the speed and convenience provided by air transport makes it absolutely essential for the competitiveness of the islands.

The Caribbean is one of the world's most vulnerable regions to climate change. Thus, as critical national infrastructure assets, airports must be protected from its effects. The increasing frequency of extreme weather events and sea level rise are of particular concern to Caribbean airports. But whereas most airports recognize these and other risks, much work still needs to be done to ensure the long-term resilience of the industry.

This study is very important and timely as it points out the areas that need to be considered to adapt the region's airports to the impacts of climate change. It is fundamental to highlight the need to approach climate change as a long-term key strategic issue, rather than taking reactive actions to catastrophic events. This also involves raising awareness and active participation at the highest level of airport management and national governments.

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SUMMARY

The Latin America and Caribbean (LAC) region is home to major global and regional hub airports, as well as many airports that are critical for economies and connectivity. ACI-LAC represents 86 members that operates more than 350 airports in 41 countries and territories in the region. Member airports handle 95% of commercial air traffic in Latin America & Caribbean, welcoming over 570 million passengers, 5.4 million tonnes of freight and more than 9.0 million aircraft movements each year.

However, across the region, the effects of climate change such as higher temperatures, sea level rise and stronger storms will threaten critical airport infrastructure and impact aircraft operations, with 83% of respondents to a survey of LAC airport stakeholders already experiencing the effects of climate change, and 100% of respondents expecting to be affected by 2050.

Airports in the region are starting to carry out climate change risk assessments and implement adaptation measures. However, given the extent of the climate change effects projected in the region, it is vital to increase and accelerate action. Five recommendations are proposed to promote and support the region's airports to adapt and build climate resilience.

This report was produced in partnership with the Airport Council International Latin America and Caribbean (ACI-LAC) and Manchester Metropolitan University.

Contents

1. INTRODUCTION: an accelerating need to adapt

For the countries of Latin America and the Caribbean (LAC), airports are vital for global connectivity, social and economic development, and sustainable growth.

ACI-LAC represents 86 members that operates more than 350 airports in 41 countries and territories. Member airports handle 95% of commercial air traffic in Latin America & Caribbean, welcoming over 570 million passengers, 5.4 million tonnes of freight and more than 9.0 million aircraft movements each year.

Climate change is increasingly impacting the LAC region, threatening critical airport infrastructure and impacting aircraft operations. The Intergovernmental Panel on Climate Change (IPCC) identifies Central and South America as highly vulnerable to, and already strongly impacted by, climatic changes, highlighting increases in temperature and changes in rainfall patterns as key risks throughout the region, and sea level rise (SLR) as a threat in coastal areas. The Caribbean will increasingly experience higher temperatures, more intense tropical cyclones, sea-level rise and changing precipitation patterns.

As a result, there is a growing need for airports in the region to adapt and build resilience to the impacts of climate change. This is essential to reduce vulnerabilities, damage and costs, whilst protecting both service continuity and critical infrastructure. Awareness of the potential impacts of climate change, and the need to adapt and build resilience, is increasing across the sector, and more airports in the region and around the globe are starting to carry out climate change risk assessments and develop adaptation strategies. But, for a multitude of reasons, many have not yet begun to take action. However, given the ever more severe climate projections from the IPCC, such action becomes increasingly urgent. Moreover, given that a disruption in one part of the network can have a knock-on effect across the region, it is vital for all the region's airports to adapt and build resilience to the impacts of climate change.

This report aims to support the region's airport sector in taking adaptation action by identifying and raising awareness of projected climate change effects and impacts in the LAC region, and actions that can be taken to adapt and build resilience. It presents the results of a survey of airports in the LAC region which gathered stakeholder views on the biggest climate challenges they expect to face, and tangible solutions for adapting and building resilience. It concludes with five recommendations to promote and accelerate climate adaptation action in the region.

2. PROJECTED CLIMATE CHANGE EFFECTS IN THE LAC REGION

Climate change effects will vary across the LAC sub-regions. Temperatures are projected to rise throughout the region, while rainfall patterns will vary with some areas experiencing an increase and others a decrease in precipitation. Sea level rise will continue around the region's coasts.

The IPCC identify 10 climate sub-regions in Latin American and the Caribbean (see **Figure 1**). Climate change effects, and in turn the impacts for airports, will vary across the region. However, in general, temperatures are projected to continue increasing at rates greater than the global average across all sub-regions of Central and Southern America. Mean precipitation is projected to increase in North-West South America (NWS) and South-East South America (SES) but to decrease in North-East South America (NES) and South-West South America (SWS). In the Caribbean (CAR) more extreme tropical cyclones are projected. Projected temperature increases in the CAR subregion are less than the global mean, however an increase in droughts is forecast to continue. Relative sea level rise is projected to increase throughout the LAC region.

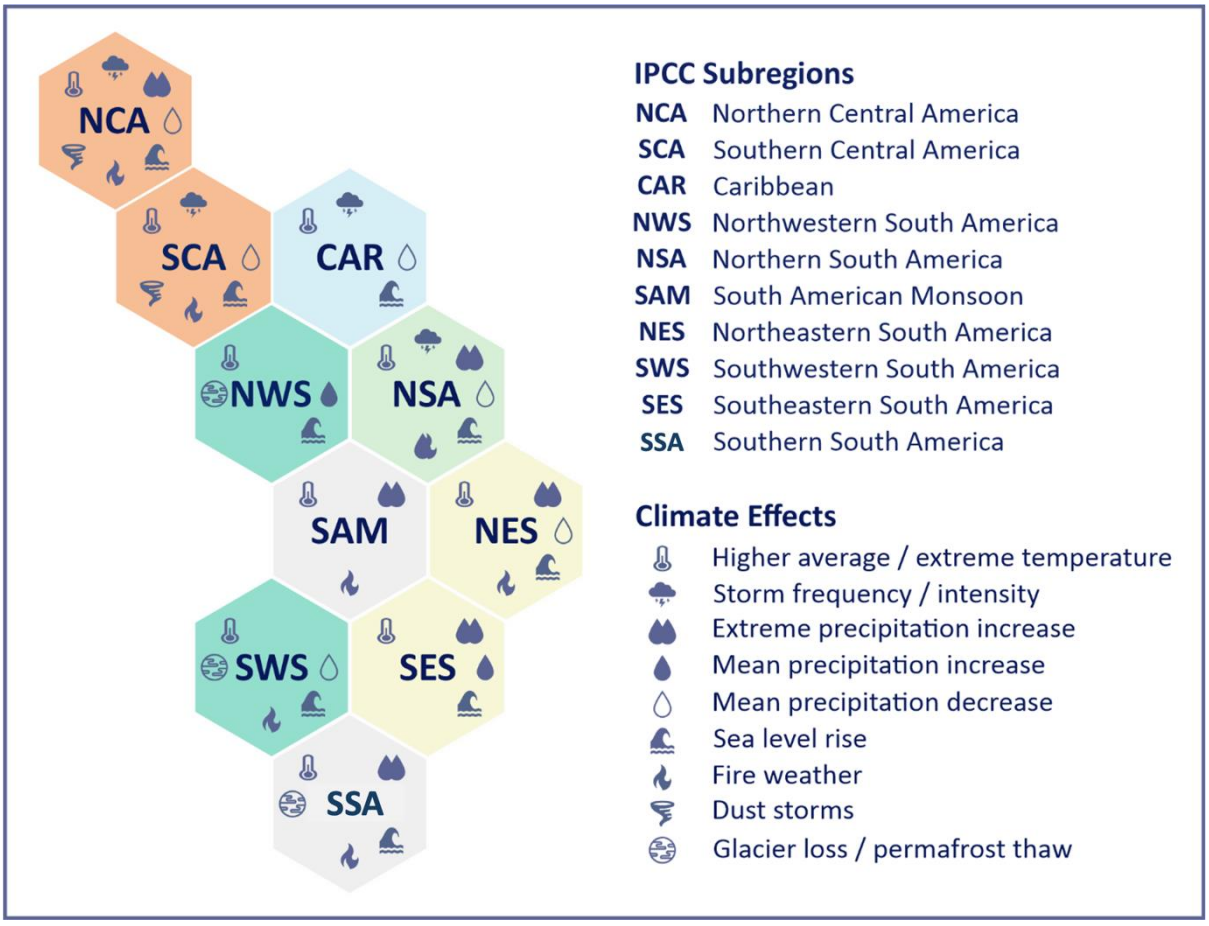

Figure 1 *Key climate change effects in the LAC IPCC subregions*

3. ACI-LAC STAKEHOLDER SURVEY 2023

3.1 Overview of the survey

To investigate the extent to which climate change is a concern for ACI-LAC airports, and the measures they are taking, or envisage, to adapt and build resilience, a questionnaire was developed and distributed to members of the Airports Council International Latin America and Caribbean (ACI-LAC) Environment Working Group between December 2022 and March 2023. It was available in both English and Spanish.

The questionnaire consisted of three sections. The first section requested information on the airport such as its location and number of passengers per annum. The second section asked about climate change effects, and any resulting impacts, which the airport was already experiencing or expected to experience in the future. The third section requested information on actions the airport had already taken on climate change risk assessment and adaptation planning, or expected to take in the future, levels of preparedness to deal with the impacts of climate change, information needs and barriers or challenges experienced.

The eleven climate change effects covered were:

1. Higher average and extreme temperatures
2. An increase in frequency and/or intensity of storms
3. An increase in frequency and/or intensity of precipitation
4. A decrease in frequency and/or intensity of precipitation
5. Sea level rise (SLR)
6. Changes to wind patterns (e.g. direction, speed or seasonality)
7. An increase in desertification and/or dust storms
8. Changes to fog patterns and/or occurrence (increase or decrease)
9. Changes to the occurrence of icing (increase or decrease)
10. Changes to wildlife patterns
11. Business and economic effects

3.2 Respondent profile

The survey of ACI-LAC airport stakeholders received 35 responses from across the region.

Thirty-five individual responses were received from 32 airports or airport groups across the LAC region, covering 53 airports in total, around 15% of the 350 ACI-LAC member airports. Responses were received from all IPCC LAC regions except SAM and SSA (**Figure 2**, see **Figure 1** for an overview of the regions). The largest number of respondents were from the Caribbean region (CAR 13/35, 37%), where extreme weather events such as hurricanes are already experienced. The second highest number of respondents were from Northwestern South America (NWS 8/35, 23%), where several of the region's major airports are located.

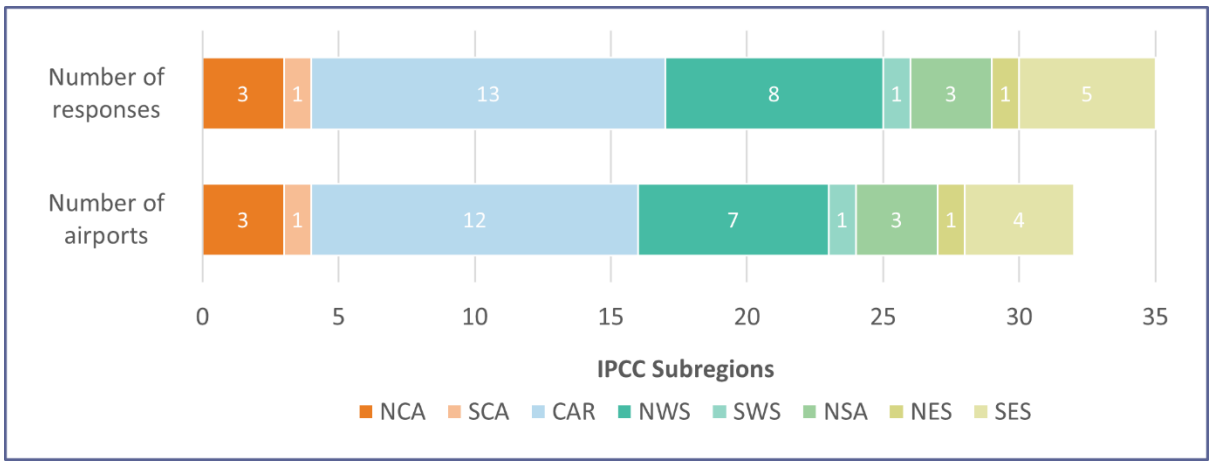

Figure 2 *Breakdown of respondents by IPCC region shown by number of responses and number of airports.*

The majority of the responding airports (28/32) were in ACI's under 2 million or 2 to 5 million passengers per annum categories (**Figure 3**). Two airports were in the 5 to 15 million passengers per annum category with one airport each in the 15 to 25 million and 25 to 40 million category[1].

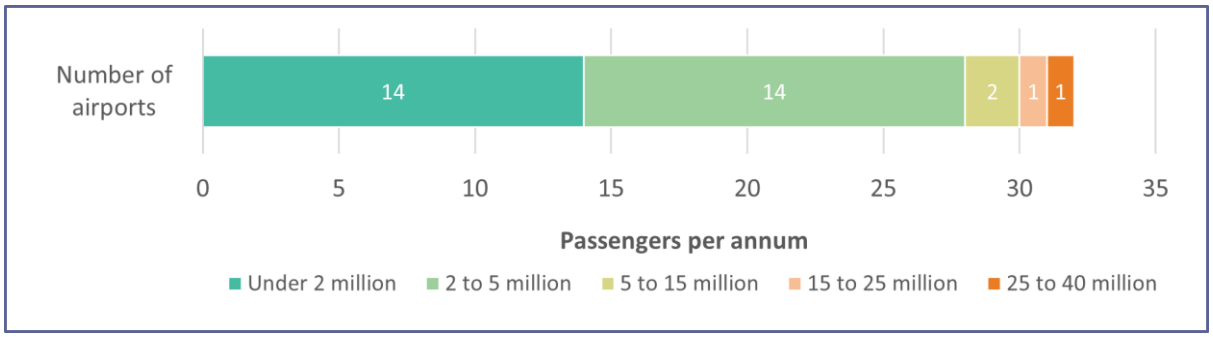

Figure 3 *Breakdown of responding airports by passenger numbers.*

[1] A breakdown of airport passenger numbers per region is not provided as some airports may have been identifiable.

4. CLIMATE CHANGE EFFECTS & IMPACTS

4.1 Timescale in which respondents expect to experience climate change effects

Ninety-one percent of survey respondents are already experiencing or expect to experience higher average and extreme temperatures, with 89% experiencing or expecting an increase in precipitation and 83% more frequent or more intense storms.

Figure 4 presents the timescale in which respondents expect to experience each of the eleven climate change effects covered by the survey. Almost all respondents are already experiencing or expect to experience higher average and extreme temperatures (32/35, 91%) and an increase in precipitation 31/35 (89%). An increase in frequency and/or intensity of storms is either already experienced or expected by 29/35 (83%) and SLR by 25/35 (71%). Just 8/35 (23%) of respondents are already experiencing or expect to experience an increase in desertification and/or dust storms and 3/35 (8.5%) a change in icing conditions.

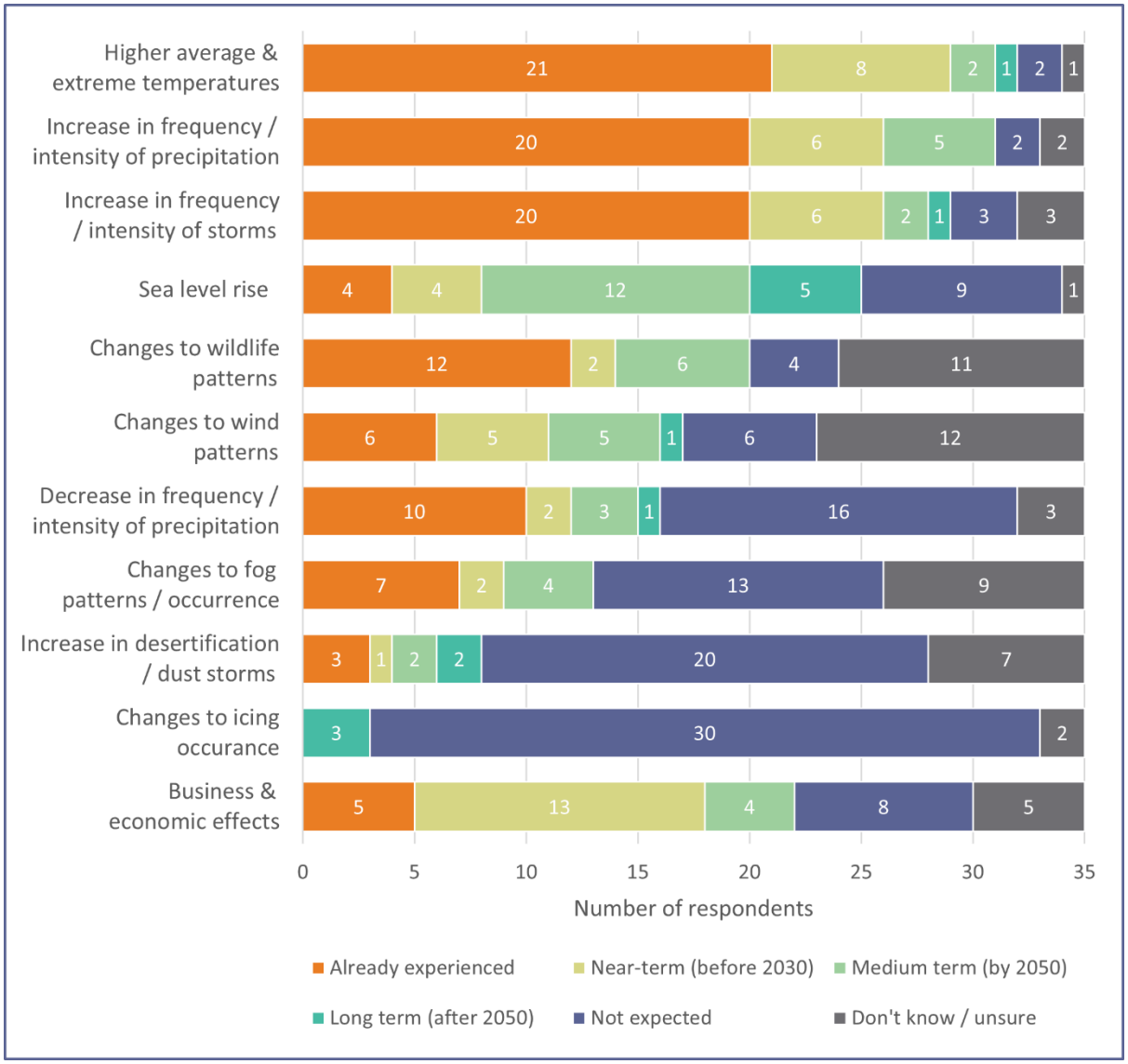

***Figure 4** Climate change effects which respondents have already experienced or expect to experience in the future (n=35)*

4.2 The number of climate change effects respondents expect to experience

Eighty-three percent of survey respondents are already experiencing at least one effect of climate change. By 2050, 100% of respondents expect to experience at least one effect, with one respondent expecting to experience all eleven effects.

At present, 29/35 (83%) of respondents are already experiencing at least one of the eleven effects of climate change covered by the survey, with 17/35 (49%) experiencing at least four effects and one respondent already experiencing eight of the eleven effects. Just 6/35 (17%) are not yet experiencing any effects of climate change (**Figure 5**).

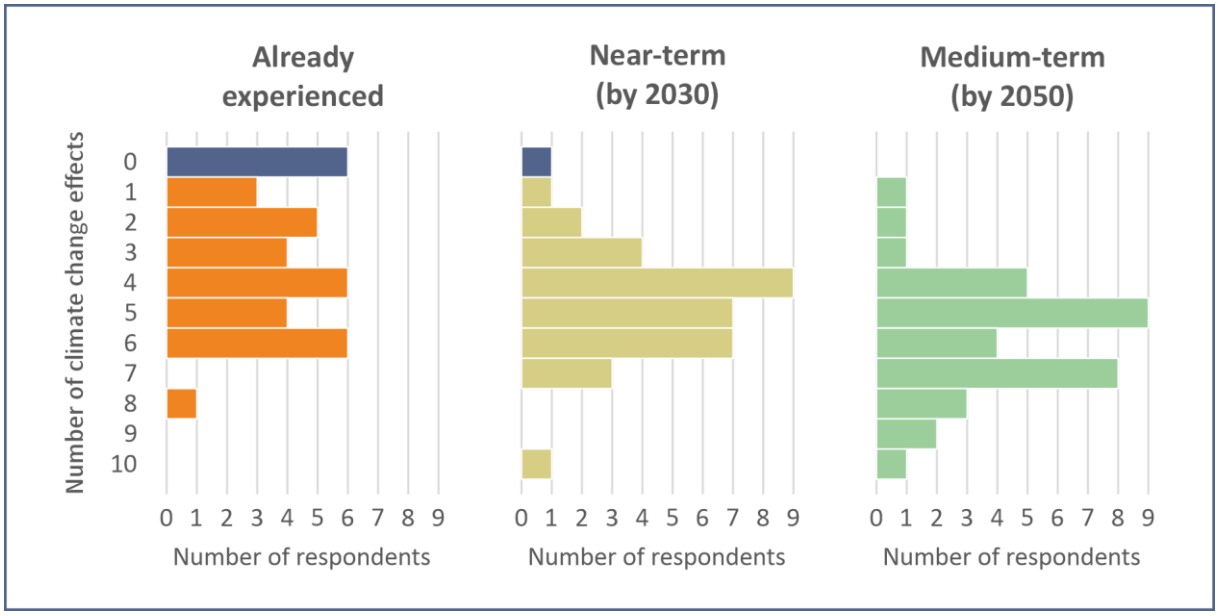

Figure 5 *Number of climate change effects which respondents have already experienced or expect to experience in the near to medium term future (n=35)*

By 2030, 34/35 respondents (97%) expect to be experiencing at least one effect of climate change, with 27/35 (77%) expecting to experience at least four effects and one respondent already expecting to experience ten out of the eleven effects. Just one respondent is not yet expecting to experience any effects (**Figure 5**).

By 2050, all 35 respondents expect to be experiencing at least one effect of climate change with 32/35 (91%) expecting to experience at least four effects and one respondent expecting to experience ten effects (**Figure 5**). The effect not yet being experienced is changes to icing occurrence.

This demonstrates how, in line with IPCC projections, respondents expect the effects of climate change to increase over time, highlighting the need for adaptation and resilience action to increase to address the growing risks.

4.3 Climate change effects and impacts respondents expect to experience

The following section will look at each climate change effect in turn, considering both the potential impacts for airports and the results of the stakeholder survey.

Higher average and extreme temperatures

Temperature increases are projected throughout the LAC region. In the Caribbean temperatures are projected to increase at less than the global average. However, in Central and Southern America temperatures are projected to continue increasing at rates greater than the global average.

Warmer air is less dense, therefore aircraft need to use more thrust to take-off. This increases the distance required and reduces the maximum take-off weight (MTOW). Therefore, a key operational risk of higher temperatures is deterioration in aircraft take-off performance. This is a particular risk for high altitude airports or those with length-limited runways. Other potential impacts include heat damage to runways and taxiways, increased fire risk, overheating of equipment, and health risks for ground personnel, staff in terminals and passengers, leading to increased cooling requirements and energy costs.

Almost all respondents to the LAC airport survey (32/35, 91%) are already experiencing or expect to experience an increase in average and extreme temperatures (**Figure 6**). Two respondents don't expect an increase and one respondent answered don't know.

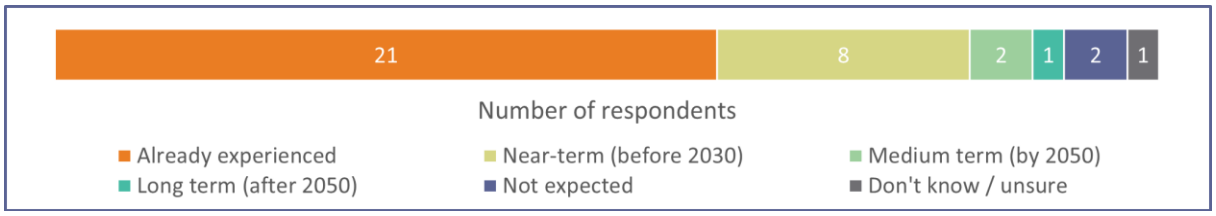

Figure 6 *Timeframe in which respondents are expecting to experience higher average and extreme temperatures (n=35)*

Figure 7 identifies some of the main impacts of higher temperatures for airports. Of the 32 respondents that are already experiencing or expect to experience higher average and extreme temperatures, 17/32 (53%) are already experiencing an increase in cooling demand for infrastructure and 30 (94%) expect to experience this impact in total. Only one respondent (3%) is already experiencing health impacts for employees and passengers, but 21/32 (66%) expect to experience this in the future. One respondent highlighted that incoming passengers from cooler climates have an unpleasant experience waiting outside the airport terminal for transportation or pickups in high temperatures. Fewer respondents are expecting impacts on aircraft performance: 12/32 (37.5%) don't expect to experience this, whilst 10/32 (31%) were unsure.

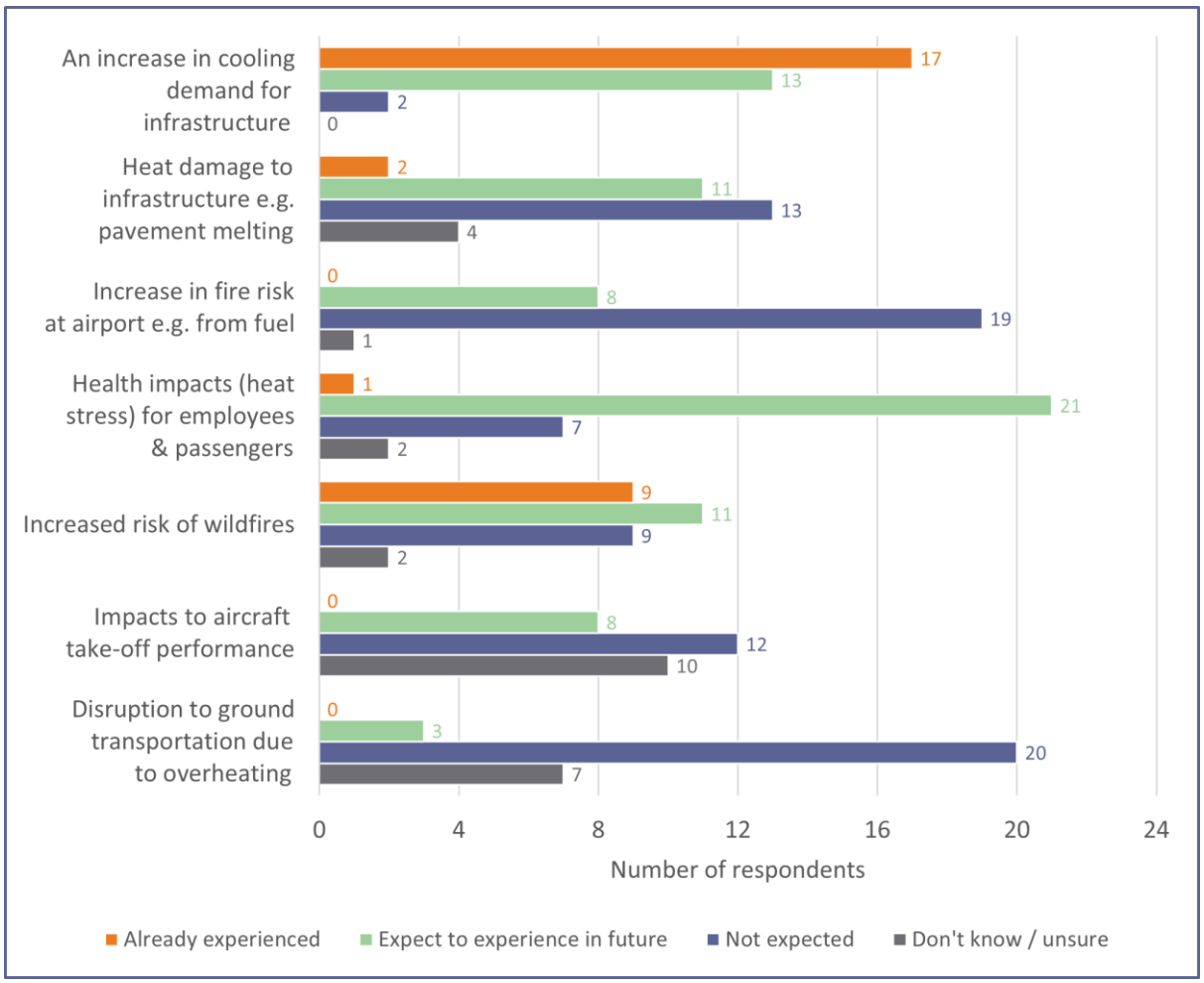

Figure 7 *Impacts of higher temperatures which respondents are already experiencing or expect to experience (n=32)*

Increase in frequency and/or intensity of precipitation

Changes in average precipitation will vary across the region with some subregions such as NWS and SES experiencing an increase in rainfall and some such as NES and SWS experiencing a decrease and risk of drought conditions. Some subregions that experience an overall decrease in precipitation, such as NSA and SES, may also experience an increase in intense rainfall events. There may also be seasonal shifts in rainfall patterns.

An increase in intensity, duration or frequency of precipitation events can cause flooding of airport infrastructure. Flooding of ground transport is also a risk. Both heavy precipitation and surface flooding can have operational impacts resulting in delay and cancellation of flights.

Twenty out of thirty-five respondents (57%) are already experiencing an increase in frequency and/or intensity of precipitation, with a further 6/35 (17%) expecting to experience it by 2030 (**Figure 8**). Just two respondents (6%) don't expect to experience an increase in frequency and/or intensity of precipitation at some point in the future.

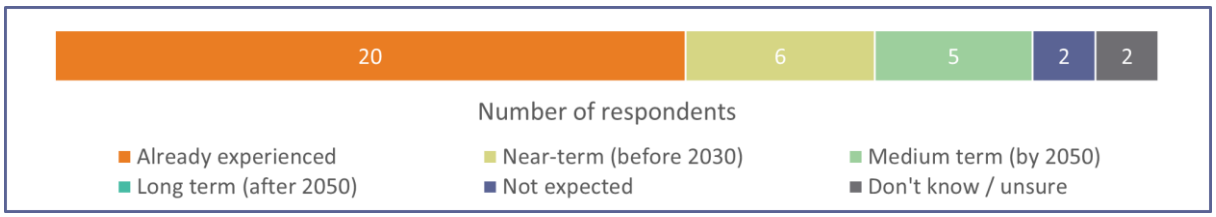

Figure 8 *Timeframe in which respondents are expecting to experience increased precipitation (n=35)*

Figure 9 identifies some of the main impacts of increasing precipitation for airports. Of the 31 respondents already or expecting to experience an increase in frequency and/or intensity of precipitation, 14 (45%) are already experiencing disruption to operations and an additional 13 (42%) expect to experience this in the future. Nine (29%) have already experienced flooding of infrastructure and 11 (35%) expect to experience it in the future. One respondent noted that an increase in rain has attracted more birds to the airport, which in turn could lead to a possible increase in bird strikes.

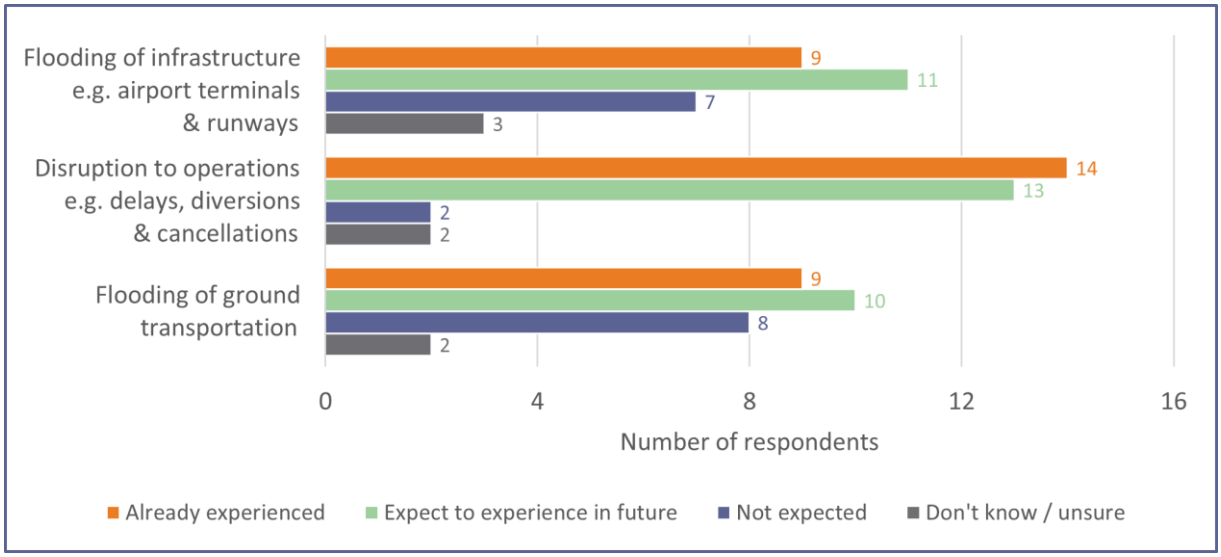

Figure 9 *Impacts of increasing precipitation which respondents are already experiencing or expect to experience (n=31)*

Increase in frequency and/or intensity of storms

The IPCC (2021) project an increase in the severity of tropical cyclones and severe storms in both Central America and the Caribbean. Storms can damage or flood airport infrastructure. They can cause operational impacts such as delays, diversions, and cancellations. Flooding from storm water can also impact ground access to airports. There may also be an increased risk of lightning strikes at airports, which has safety and operational impacts, while for coastal airports storm surges are a risk.

Twenty out of thirty-five (57%) respondents have already experienced an increase in frequency and/or intensity of storms, with 6/35 (17%) expecting to experience an increase by 2030 (**Figure 10**). Just 3/35 (9%) of respondents don't expect to experience an increase in frequency and/or intensity of storms at some point in the future.

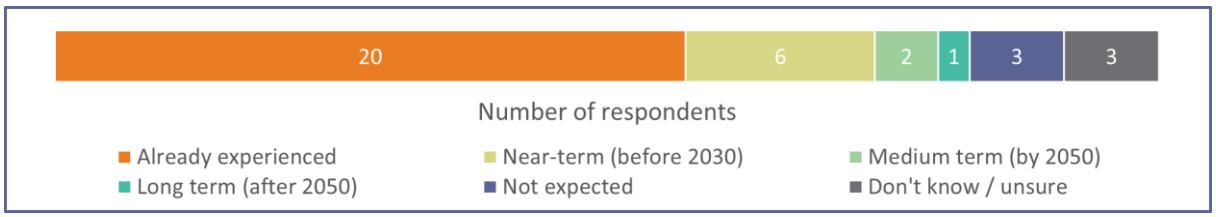

***Figure 10** Timeframe in which respondents are expecting to experience an increase in storms (n=35)*

Figure 11 identifies some of the main impacts of an increase in frequency and/or intensity of storms for airports. Of the 29 respondents that are already experiencing or expect to experience an increase in frequency and/or intensity of storms 26/29 (90%) are already experiencing or expect to experience disruption to operations, 18/29 (62%) are already experiencing or expect to experience flooding of infrastructure and 17/29 (59%) are already experiencing or expect to experience damage to infrastructure. Relatively less respondents (14/29, 48%) are already experiencing or expect to experience an increase in lightning strikes. A respondent also highlighted the risk of storms outside of the rainy season as well as an increase in atypical rains.

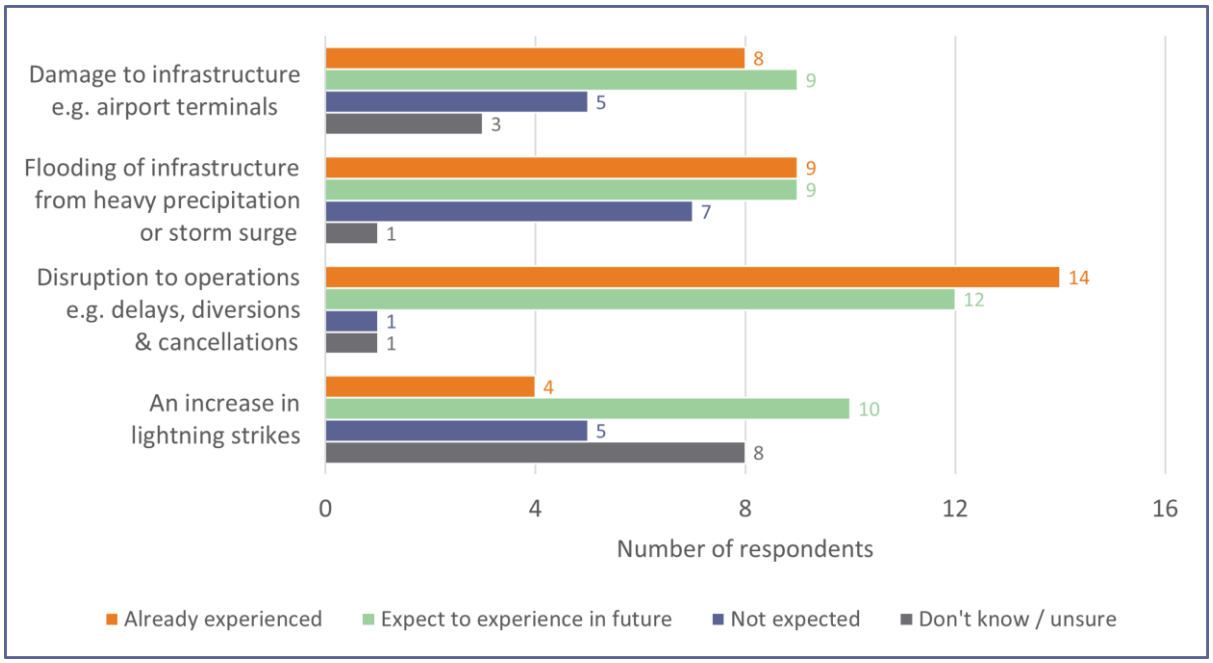

***Figure 11** Impacts of increasing storms which respondents are already experiencing or expect to experience (n=29)*

Sea level rise

Relative sea level rise is projected to continue in the LAC region's oceans. However, it is a longer-term risk which most airports, with some exceptions, expect to experience in the medium to longer term. It is also a geographically-specific risk directly affecting low-lying, coastal airports. Flooding of runways and taxiways can impact airport capacity causing delays, diversions, cancellations and temporary airport closures. In extreme cases, airports may need to close permanently or relocate from sea level rise or storm surge. Ground transport access may also be at risk of flooding. There may also be indirect impacts for other airports due to traffic disruption or temporary or permanent closure.

Twenty-five of thirty-five (71%) of survey respondents are already experiencing or expect to experience sea level rise, with 4/35 (11%) already experiencing some effects and 4/35 (11%) expecting to be affected by 2030 (**Figure 12**).

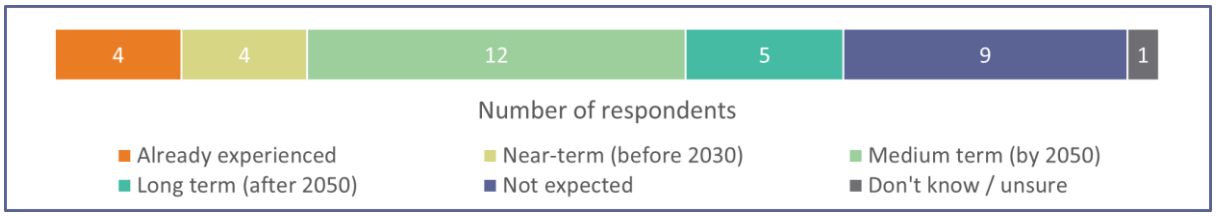

***Figure 12** Timeframe in which respondents are expecting to experience sea level rise (n=35)*

Figure 13 identifies some of the main impacts of sea level rise for airports. Of the 25 respondents that are already experiencing or expect to experience sea level rise, seven (28%) are already experiencing temporary flooding of infrastructure and nine (36%) expect to experience it in the future. Although no respondents have yet experienced permanent flooding of infrastructure, five (20%) expect to experience it in the future. Three (12%) are already experiencing flooding of ground transport, with 14 (56%) expecting to experience it in the future, and although no respondents have already experienced disruption to operations due to sea level rise, 16 (64%) expect to experience it in the future.

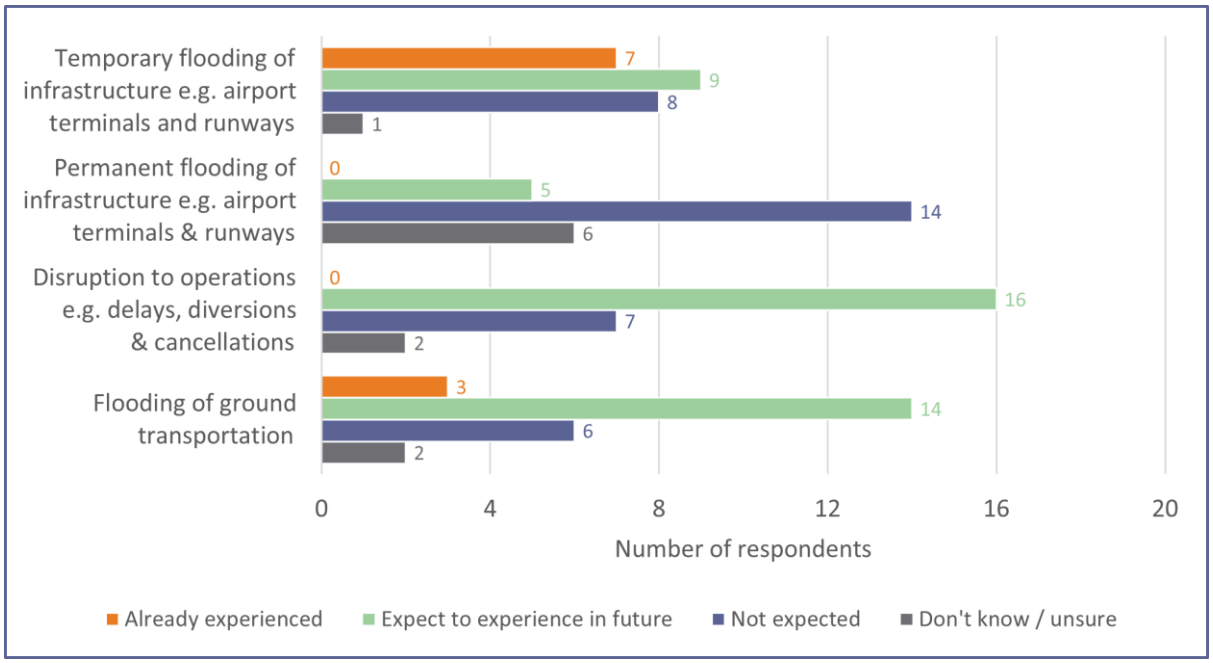

***Figure 13** Impacts of sea level rise which respondents are already experiencing or expect to experience (n=29)*

Changes to wildlife patterns

Climate change will alter ecosystems and change species migration patterns. New bird migration patterns may cause an increase in bird strikes, which has safety and operational impacts. There may also be knock-on effects, for example, changes to vegetation can attract more birds which in turn can lead to more bird strikes. Or, as noted by a survey participant, an increase in precipitation may attract more birds to an area which in turn may increase risk of bird strikes.

Overall, 20/35 (57%) respondents are already experiencing or expect to experience changes in wildlife patterns at some point in the future, with 12/35 (34%) already experiencing changes (**Figure 14**).

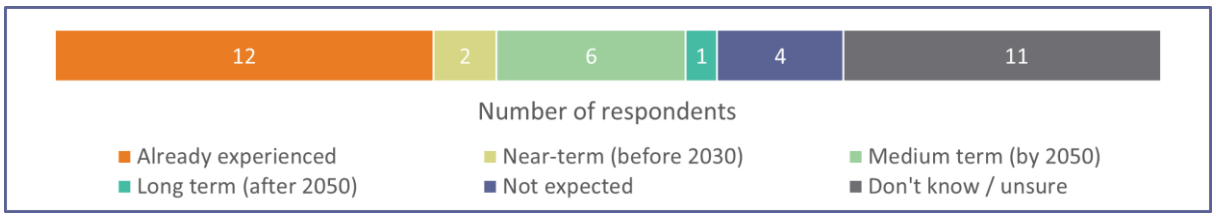

***Figure 14** Timeframe in which respondents are expecting to experience changes to wildlife patterns (n=35)*

Figure 15 identifies some of the main impacts of changes in wildlife patterns for airports. Of the 20 respondents that are already or expect to experience changes in wildlife patterns 9/20 (45%) are already experiencing an increase in bird strikes and 8/20 (40%) expect to experience an increase in the future. 8/20 (40%) are already experiencing changes in wildlife migration patterns and 8/20 (40%) expect to experience change in the future. 16/20 (80%) are already experiencing or expect to experience changes in vegetation patterns.

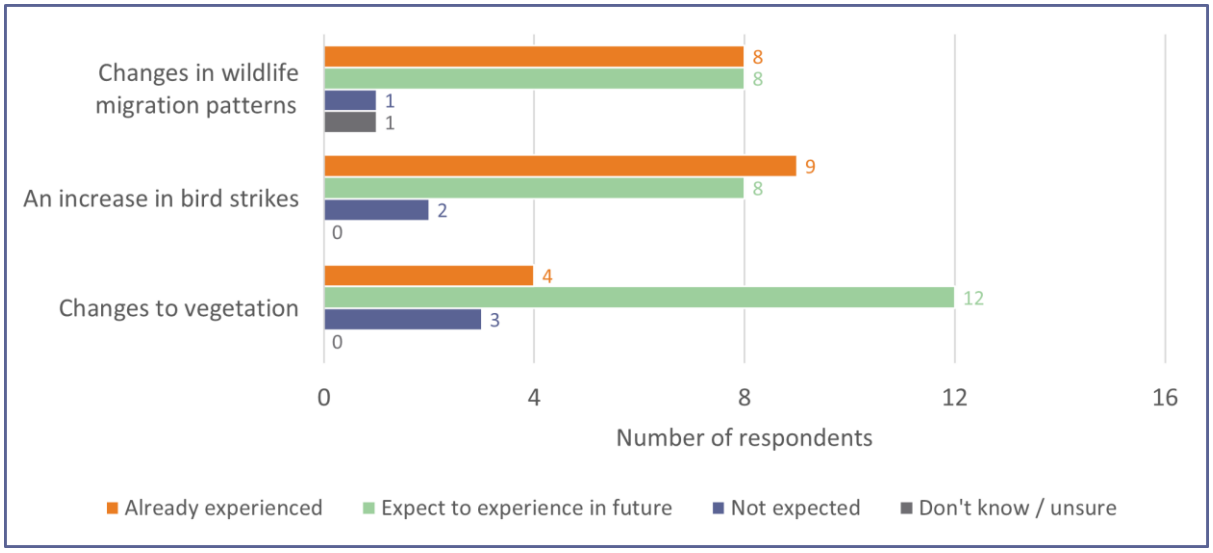

***Figure 15** Impacts of wildlife changes which respondents are already experiencing or expect to experience (n=20)*

Changes in wind patterns

According to the IPCC, global climate models project an increase in wind speeds in most parts of Central and South America, particularly in NES. The exception is SSA where wind speeds are projected to decrease. There is limited data on changes in wind patterns available for the Caribbean, although some suggestion that a slight increase in wind speed under higher climate change scenarios.

Changes in wind patterns can include alterations to high altitude winds and variations in local winds such as differing wind speeds or directions. Strong winds can impact airport operations, reducing capacity and causing delays. They can damage airport infrastructure and aircraft at terminals, and increase safety risks for personnel. Deviation from prevailing wind direction and an increase in crosswinds can impact operations and lead to delays.

Seventeen out of thirty-five survey respondents (49%) are already experiencing changes in wind patterns, with a further 7/17 (41%) expecting to experience changes in the short to medium term (**Figure 16**).

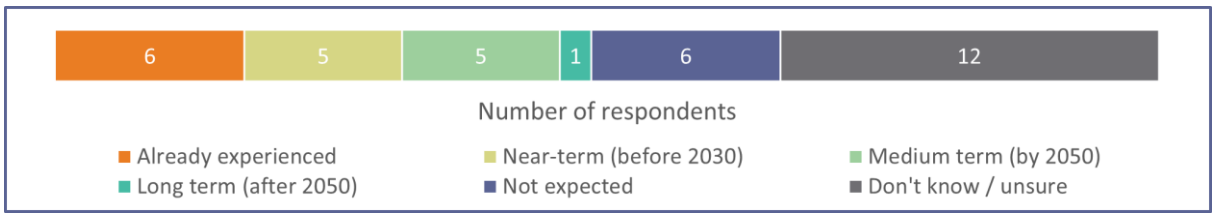

Figure 16 *Timeframe in which respondents are expecting to experience changes in wind patterns (n=35)*

Figure 17 identifies some of the main impacts of changes in wind patterns for airports. Of the 16 respondents that answered the follow-up question on impacts, 12/16 (75%) are already experiencing or expect to experience disruption to operations due to strong winds and 12/16 (75%) %) are already experiencing or expect to experience disruption due to deviations in the prevailing wind direction and/or an increase in crosswinds. 8/16 (50%) are already experiencing or expect to experience wind damage to infrastructure. One respondent noted that increased wind speeds could cause dust particles to be lifted which could reduce visibility.

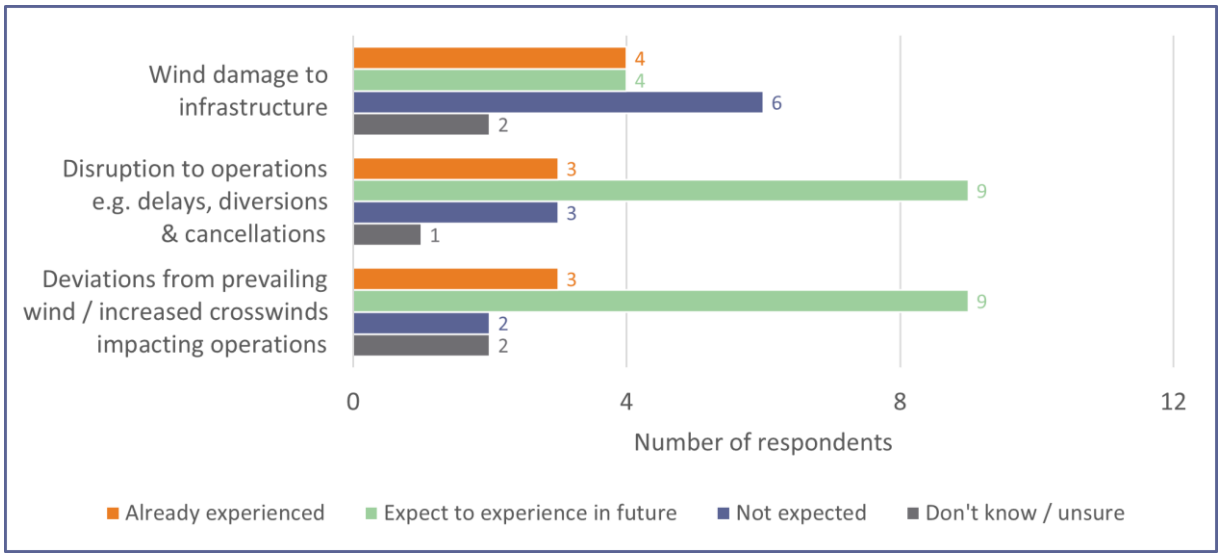

Figure 17 *Impacts of changing wind patterns which respondents are already experiencing or expect to experience (n=16)*

Decrease in frequency and/or intensity of precipitation

Whilst some subregions are expected to see an increase in precipitation, others such as CAR, NCA, SCA, NSA and SWS are projected to see a decrease with drought conditions forecast in CAR, NCA, SCA and NSA. Nevertheless, some subregions such as NSA and SES may experience an increase in *extreme* rainfall events despite an overall decrease in precipitation. According to the IPCC CAR has already experienced such an increase in heavy precipitation events, although there is less certainty as to whether this trend will continue.

Reduced precipitation can lead to water restrictions. It can also cause clay to dry-out, shrink and crack leading to damage to infrastructure.

Ten out of thirty-five survey respondents (29%) are already experiencing a decrease in precipitation with a total of 16/35 (46%) expecting to experience a decrease now or in the future (**Figure 18**).

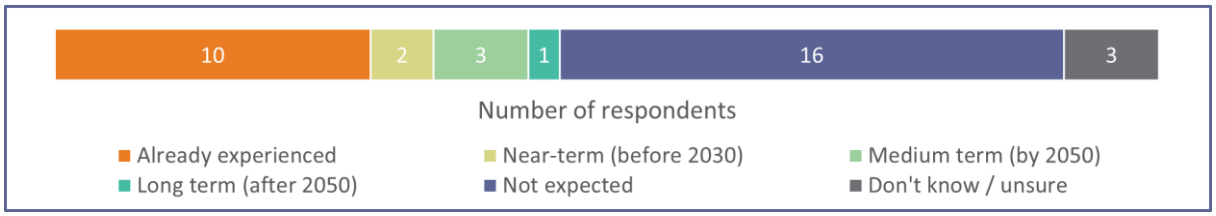

Figure 18 *Timeframe in which respondents are expecting to experience a decrease in precipitation (n=35)*

Figure 19 identifies some of the main impacts of a decrease in precipitation for airports. Of the 15 respondents that answered the follow-up question on impacts, 10/15 (67%) are already experiencing or expect to experience water shortages and restrictions. More positively, just 3/15 (75%) %) expect to experience damage to infrastructure due to shrinking of clay.

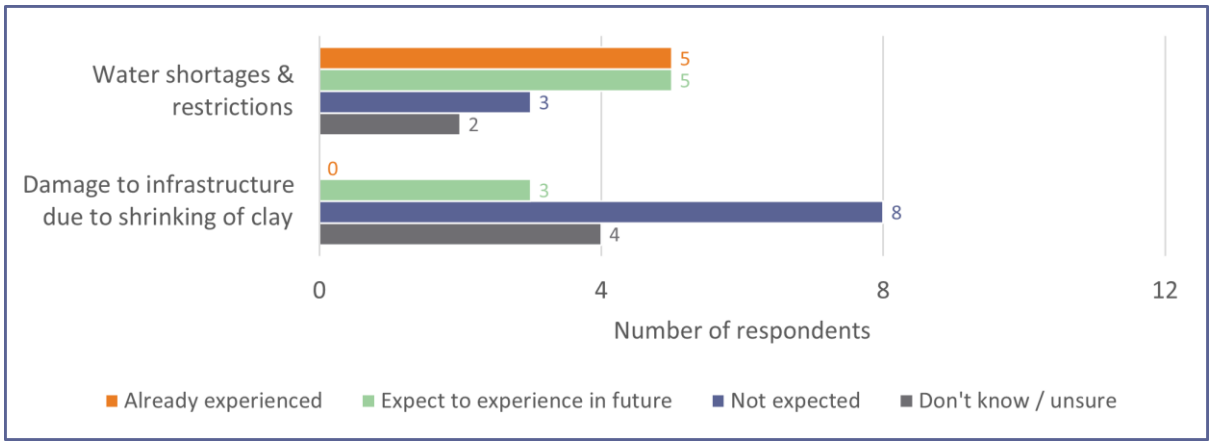

Figure 19 *Impacts of a decrease in precipitation which respondents are already experiencing or expect to experience (n=15)*

Changes in fog patterns and/or occurrence

Fog reduces visibility which can cause delays and cancellations. Changes to fog are uncertain and will vary geographically. More frequent occurrence of fog would increase operational impacts whereas a decrease would have a more positive impact by reducing them.

Thirteen out of thirty-five (67%) of survey respondents expect to experience changes in fog occurrence, with 7/35 (20%) already experiencing changes and a further six expecting them in the short to medium term (**Figure 20**).

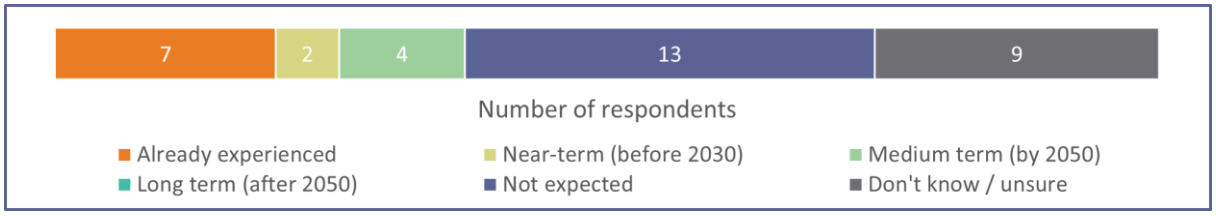

Figure 20 *Timeframe in which respondents are expecting to experience changes in fog patterns (n =35)*

Figure 21 identifies two main impacts of changes in fog occurrence for airports. Of the 13 respondents that already experiencing or expecting changes in fog patterns 12/13 (92%) are already experiencing or expect an increase in occurrence to impact operations. Conversely, no respondents are already experiencing a decrease in fog occurrence and just three expect to experience a decrease in the future.

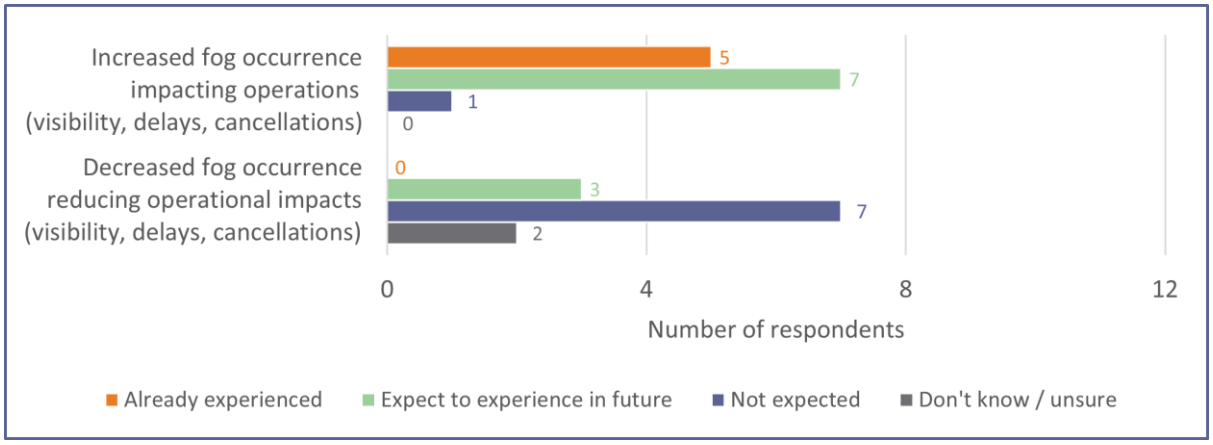

Figure 21 *Impacts of a changes in fog patterns which respondents are already experiencing or expect to experience (n = 13)*

An increase in desertification and/or dust storms

The IPCC project that dust storms will become more extreme, particularly in NCA and SCA. Desertification can lead to encroachment of sand dunes, erosion around the runway and apron, and impact water supplies. Dust storms can impact operations and safety, damage aircraft and even cause engine failure.

Eight out of thirty-five respondents (23%) are already experiencing or expect to experience an increase in desertification and/or dust storms, with 5/35 (14%) already experiencing an increase and 3/35 (9%) expecting an increase in the future (**Figure 22**).

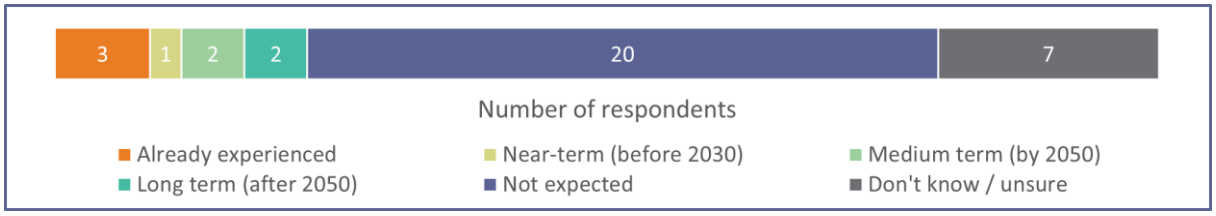

Figure 22 *Timeframe in which respondents are expecting to experience an increase in desertification or dust storms (n =35)*

Figure 23 identifies some of the main impacts of an increase in dust storms and/or desertification for airports. Of the eight respondents that are already or expect to experience an increase in dust storms and/or desertification 7/8 (87.5%) are already experiencing water shortages or expect to experience an increase in the future. 5/8 (62.5%) are already experiencing or expect dust or sandstorms to impact operations and 3/8 (37.5%) encroachment of desert sand on the airport. Although not yet being experienced by respondents, 3/8 (37.5%) expect to experience sand erosion of the runway in the future and 2/8 (25%) damage to aircraft on stands from dust or sandstorms.

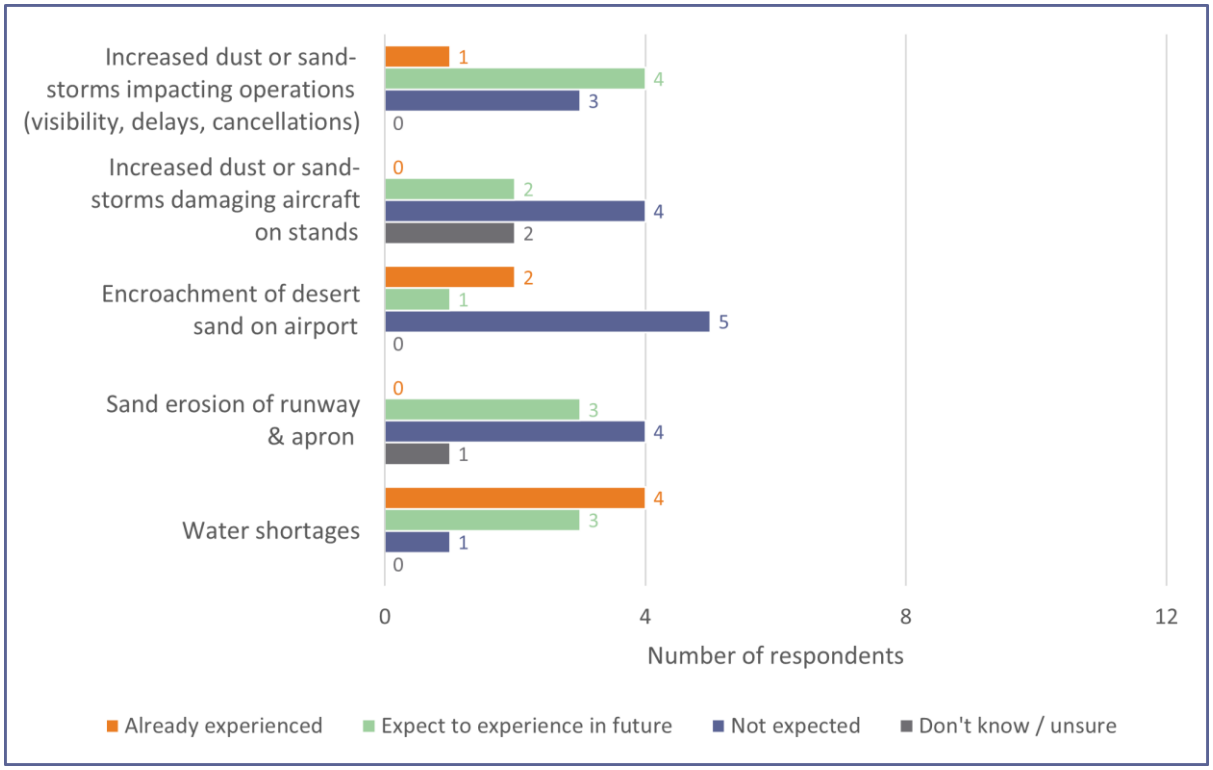

Figure 23 *Impacts of an increase in desertification/dust storms which respondents are already experiencing or expect to experience (n=8)*

Changes in icing occurrence

Build-up of ice on aircraft on the ground can lead to delays while they are de-iced, and potential pollution issues due to de-icing run-off. Therefore, a potential reduction in de-icing requirements would be a benefit.

Overall, survey respondents do not expect icing occurrence to change significantly in the region. Just three respondents are expecting a change in icing occurrence after 2050, while two answered don't know (**Figure 24**). The other 30/35 respondents (86%) don't expect to experience changes in the occurrence of icing.

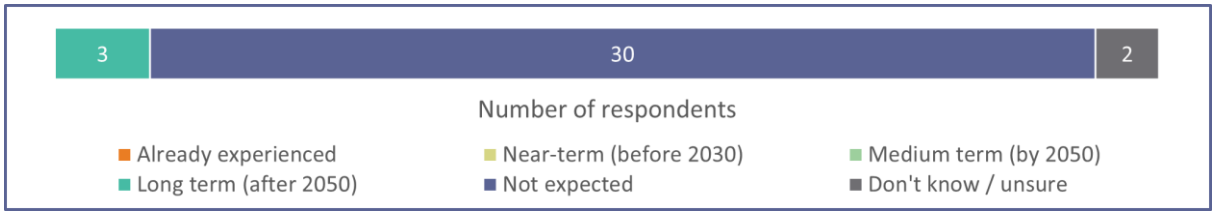

Figure 24 *Timeframe in which respondents are expecting to experience changes in icing occurrence (n=35)*

Business and economic effects

Changes in climatic conditions, such as more extreme weather or higher temperatures, are expected to influence tourists' destination choices. This may reduce tourist arrivals at some locations, increase tourism at other locations or see seasonal changes in tourists' destination preferences. This may impact airport infrastructure planning and staffing requirements. Worsening climate conditions are expected to drive an increase in infrastructure and operating costs, for example due to an increase in infrastructure damage or delay and cancellation of flights. An increase in the probability of damaging and disruptive events may drive an increase in insurance premiums.

Business and economic effects are not perceived as a current risk for the majority of survey respondents but may be an important future challenge. Although only 5/35 (14%) of respondents are already experiencing business and economic effects an additional 13/35 (37%) expect to experience them in the near-term (before 2030) and 22/35 (63%) expect to experience them overall (**Figure 25**).

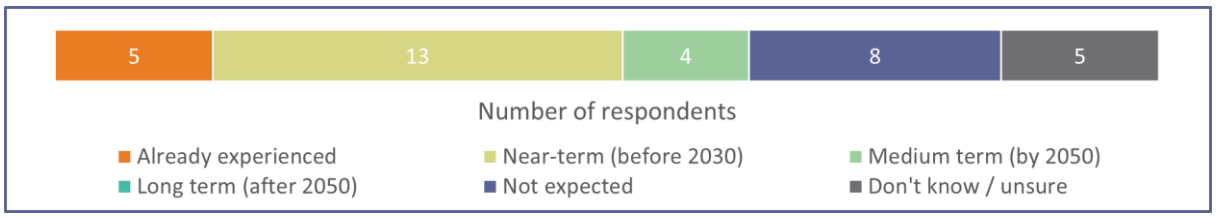

Figure 25 *Timeframe in which respondents are expecting to experience business and economic effects (n=35)*

Figure 26 identifies some of the main impacts of business and economic effects for airports. Of the 22 respondents that are already experiencing or expect to experience the impacts of business and economic effects, 21/22 (95%) are already or expect to experience an increase in operating costs, 20/22 (91%) an increase in insurance premiums and 17/22 (77%) climate-change driven changes in traffic and tourism demand.

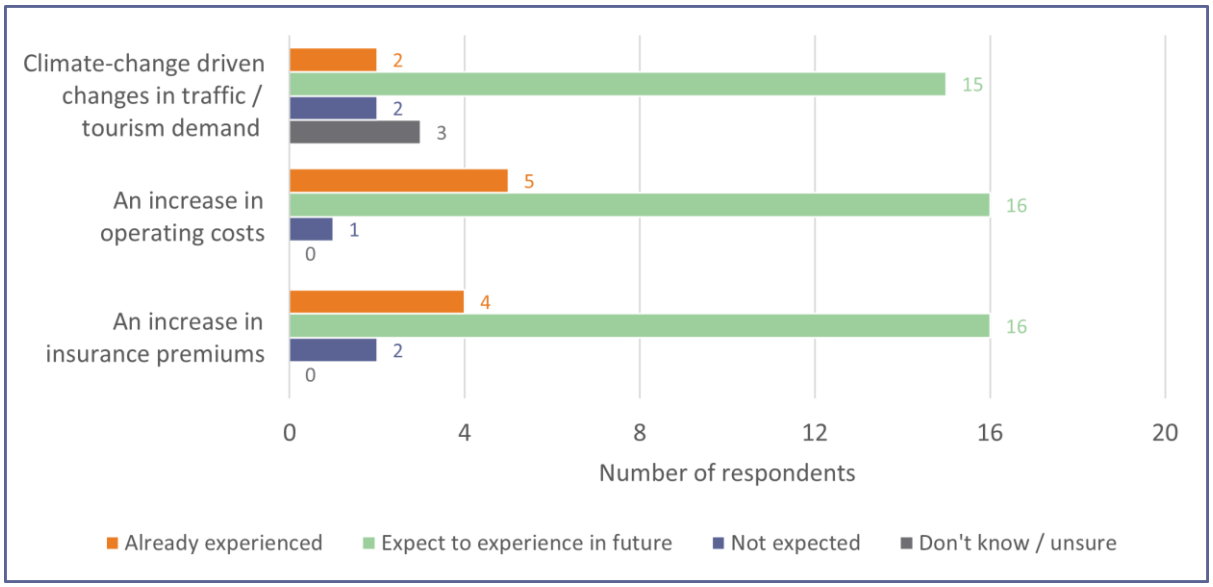

Figure 26 *Impacts of business and economic effects which respondents are already experiencing or expect to experience (n=22)*

4.4 Most significant climate change challenges for LAC airports

An increase in precipitation, higher average and extreme temperatures, an increase in storms, and sea level rise are the climate change effects which survey respondents expect to be the biggest challenge at their airports.

Survey respondents were asked to identify up to three climate change effects (and the associated impacts) that they expect to be the most significant challenges for their airport.

The majority of responses referred to a physical climate effect with ninety inputs received from 31 of the 33 respondents (**Figure 27**). Nineteen respondents identified associated impacts with 34 inputs received (**Figure 28).**

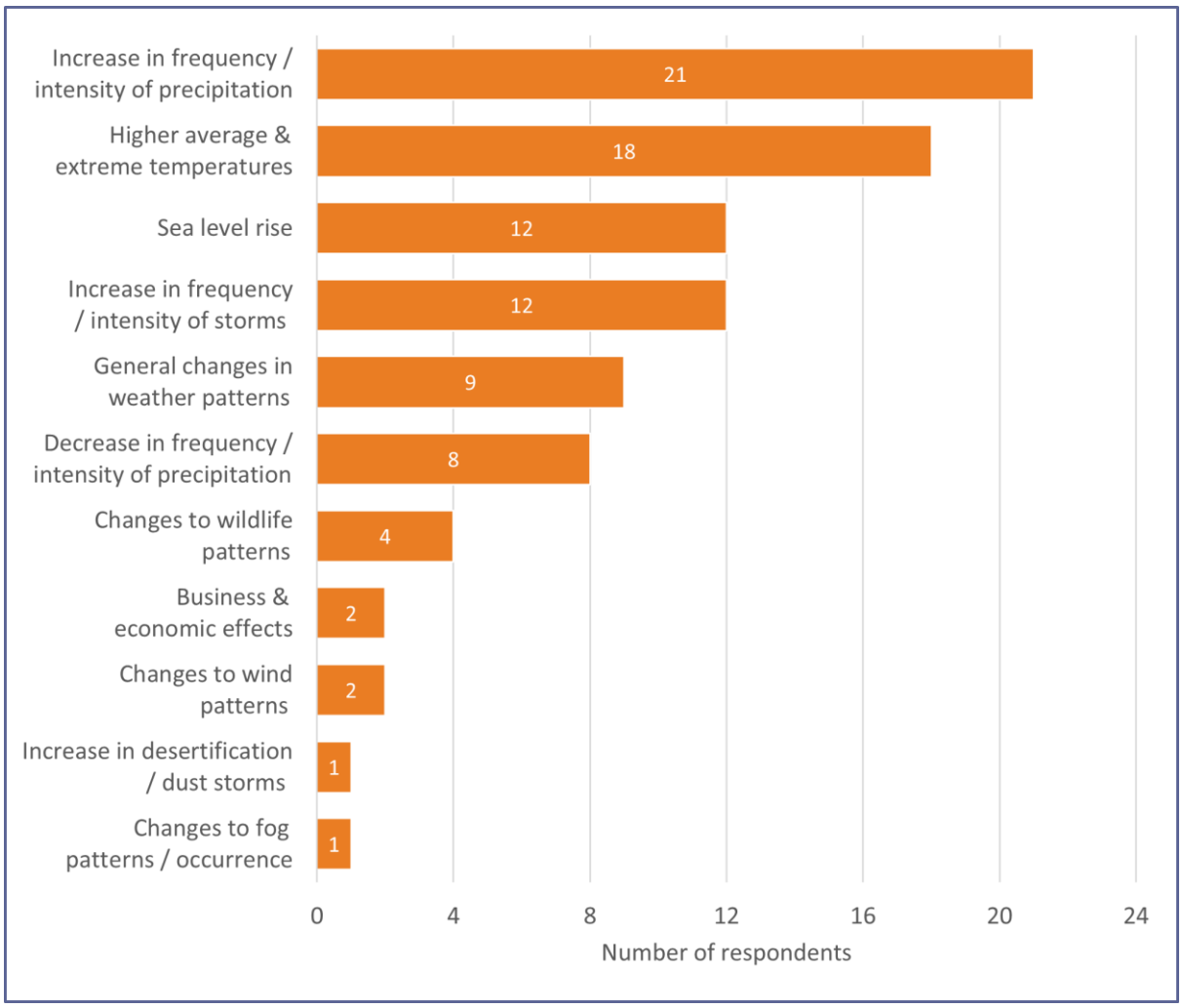

Figure 27 *Climate change effects which respondents expect to be the most significant challenge for their airport (n = 33)*

Overall, respondents considered increased precipitation as the most significant challenge (21/33 respondents, 64%), with higher average and extreme temperatures as the second biggest challenge (18/33 respondents, 55%) and increase in frequency and/or intensity of storms and SLR as the third biggest challenges (12/33 respondents, 36%), indicating that these are effects of concern across the region. More general changes in weather patterns, such as more extreme events or seasonal shifts, are projected to have an effect across the region. They are a significant concern for 9/35 respondents (27%) while decreased precipitation is expected to be a challenge for 8/33 respondents (24%). Effects such as changes to wind patterns, wildlife and fog were cited as a significant challenge by a relatively small number of respondents, suggesting that although they are not a key concern for the majority of respondents, in some specific local situations they are considered a significant challenge.

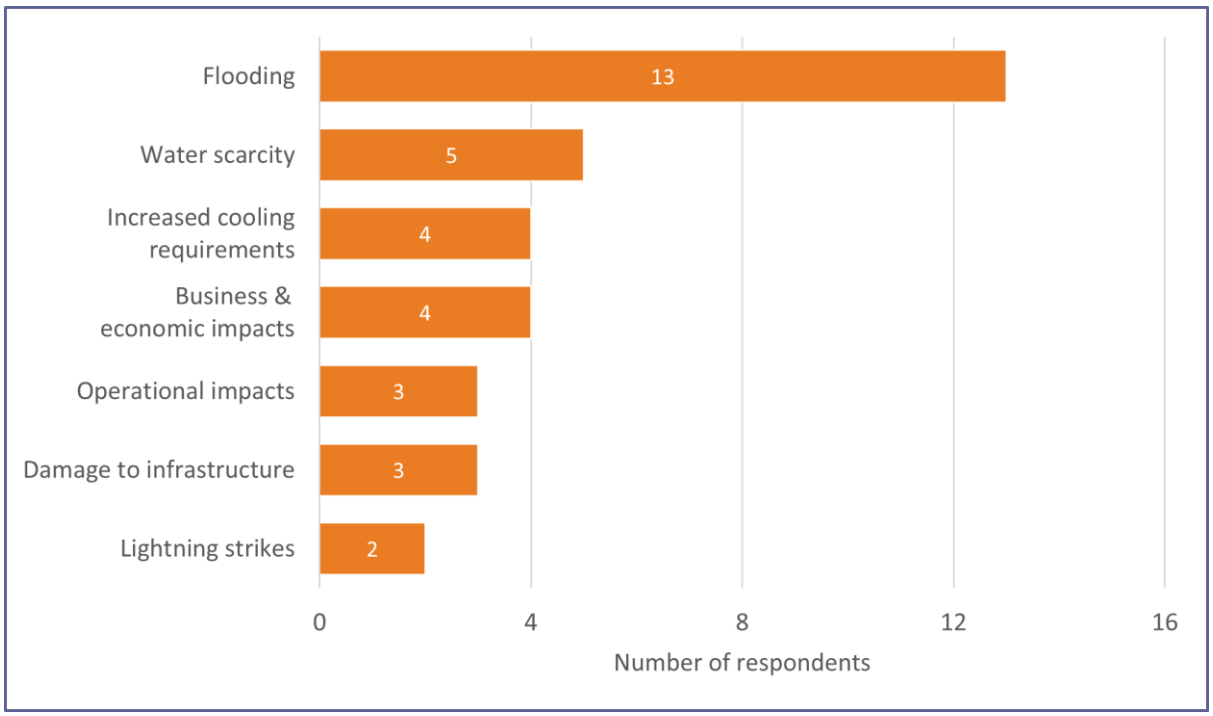

Figure 28 *Climate change impacts which respondents expect to be the most significant challenge for their airport (n=19)*

The impact which respondents expect to be most challenging is flooding (13/33, 39%), due to one or more effects such as heavy precipitation, increase in frequency and intensity of storms, or sea level rise. Respondents' concerns included flooding of infrastructure, runways and taxiways, and ground transport access. Water scarcity, due to a decrease in precipitation, is expected to be a significant challenge for 5/33 respondents (15%) whilst an increase in cooling requirements due to higher temperatures is a concern for 4/33 respondents, with both health impacts for passengers and personnel and an increase in emissions due to increased cooling demand cited as resultant impacts.

Business and economic impacts cited by respondents as significant challenges include a decrease in airport revenues, energy shortages and a decrease in beach tourism due to an increase in rainfall. Operational impacts due to effects such as an increase in temperatures, fog or precipitation were a significant concern for three respondents, potentially resulting in additional impacts such as non-compliance with service provisions or the need for investment in advanced landing aids. Damage to and/or accelerated deterioration of infrastructure is expected to be a significant challenge for three respondents. An increase in lightning strikes is a risk for personnel, infrastructure and operations and was cited as a significant concern for two respondents.

5. CLIMATE CHANGE RISK ASSESSMENT AND ADAPTATION ACTION

A climate change risk assessment is recommended to identify the climate effects and impacts for which an airport needs to prepare. Once potential impacts are understood, measures can be identified to adapt and build resilience.

For an airport to identify and understand the potential climate change effects and impacts that it may be vulnerable to, industry good practice recommends carry out a climate change risk assessment. This is a step-by-step process, usually based on local or regional climate projections to identify how climate change effects will evolve and the resulting impacts that an airport may be at risk of facing. This will vary depending on factors such as the airport's geographical location, the current climate and projected future changes, and operational and infrastructure specifics, therefore it is highly recommended for each airport to carry out its own individual risk assessment. The results of the assessment can then be used to prioritize key impacts and identify and implement appropriate measures to adapt and build resilience.

Sections 5.1 and 5.2 look at the extent to which airports in the LAC region are already engaging with risk assessment and adaption action or intend to do so in the future. Section 5.3 considers measures that can support airports in risk assessment and adaptation planning. Section 5.4 provides an overview of the main climate adaptation measures being implemented or planned by LAC airports. Section 5.5 reports on the extent to which respondents consider their airport is well-prepared to deal with the impacts of climate change.

The Directory of Adaptation Measures (section 8) at the end of this report provides more information on the various adaptation options that are available. For more information on carrying out a risk assessment and implementing an adaptation plan, see section 9 Key Resources at the end of this report.

5.1 Climate change risk assessment at LAC airports

18% of survey respondents have carried out a climate change risk assessment, with 32% intending to do so. Lack of resources, expertise or no current obligation may be preventing airports from engaging in climate risk assessment.

Of the 28 individual airports that answered the question on climate change risk assessment (**Figure 29**), five (18%) have already carried out a climate change risk assessment. One airport was in the process of carrying out a risk assessment at the time of the survey and nine airports (32%) stated that they intend to carry one out. Eight airports did not know whether or not a risk assessment was planned. Of the five airports that don't currently intend to carry out a climate change risk assessment, three cited no existing requirement or obligation to do so as the main reason, although resources and expertise were also concerns. One airport noted that although no assessment is currently planned it is something to consider in the future, and one airport clarified that although no specific climate change risk assessment is planned, all risks are regularly looked at as part of the airport's overall risk management programme, demonstrating a potential option for airports that are not currently in a position to carry out a full climate change risk assessment.

The four airports with over 5 million passengers per annum have all either already carried out a risk assessment, are in the process of carrying one out, or intend to carry one out. For airports with less than 5 million passengers per annum, three have already carried out an assessment and eight intend to do so. However, all five airports that do not intend to carry out a risk assessment and all eight that don't know whether a risk assessment is planned are in the under 5 million passengers per annum category suggesting that tackling climate change risk assessment and adaptation action may be a greater challenge for smaller airports where fewer resources may be available, and therefore additional support may be required.

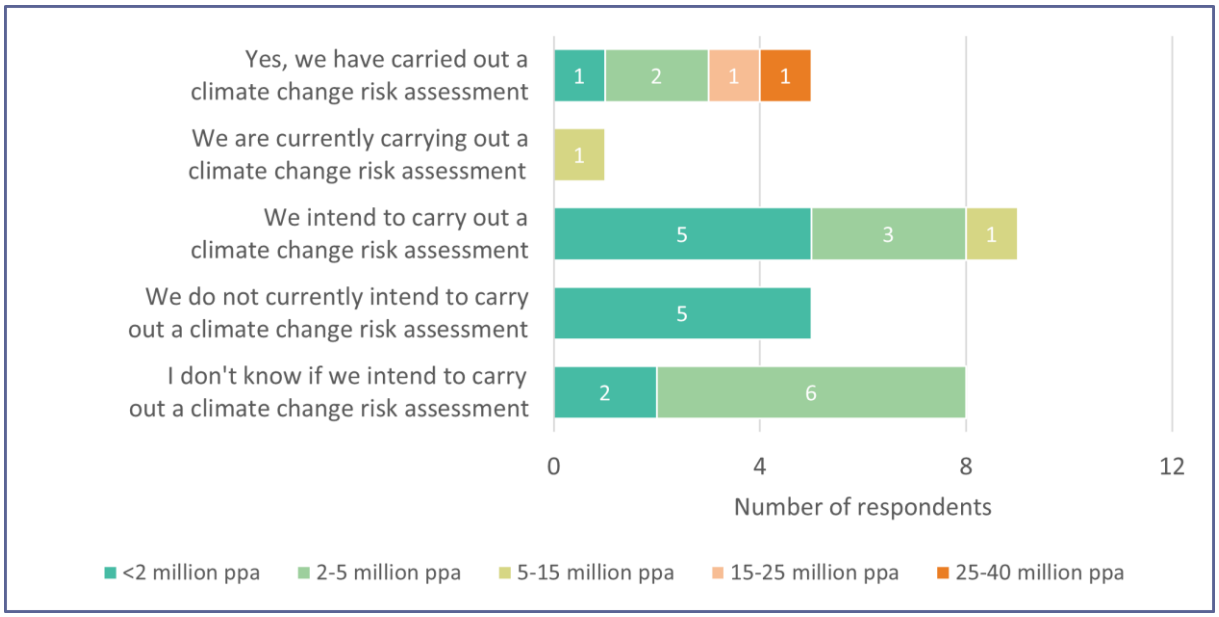

Figure 29 *Respondents' risk assessment status (n=28)*

5.2 Climate change adaptation at LAC airports

Respondents are still in the early stages of taking adaptation action, with just one airport having implemented an adaption plan, one in the process of doing so and nine planning to. Several airports have implemented ad-hoc measures to address specific risks.

Although five airports have carried out a climate change risk assessment just one to date has implemented a climate change adaptation strategy or plan, and one was in the process of implementing a strategy or plan at the time of the survey (**Figure 30**). Both airports have over 15 million passengers per annum. Nine airports intend to implement a climate adaptation strategy or plan while ten have not implemented a full plan or strategy but have implemented some ad-hoc adaptation measures.

One airport noted that although the airport itself will not implement a climate adaptation strategy or plan, responsibility for climate adaptation for the national transportation system falls under a government ministry. Just two airports have not implemented any ad-hoc measures and do not currently intend to implement an adaptation strategy and four do not know if it is currently planned to implement an adaptation strategy or plan. The two airports that don't currently intend to implement a climate adaptation strategy or plan both stated that there was no pressing need as climate impacts were not yet significant.

Of the five airports that do not currently intend to carry out a climate change risk assessment, two have implemented ad-hoc adaptation measures, two do not currently intend to develop a climate change adaptation strategy or plan and one does not know if it is currently intended to develop an adaptation plan or strategy.

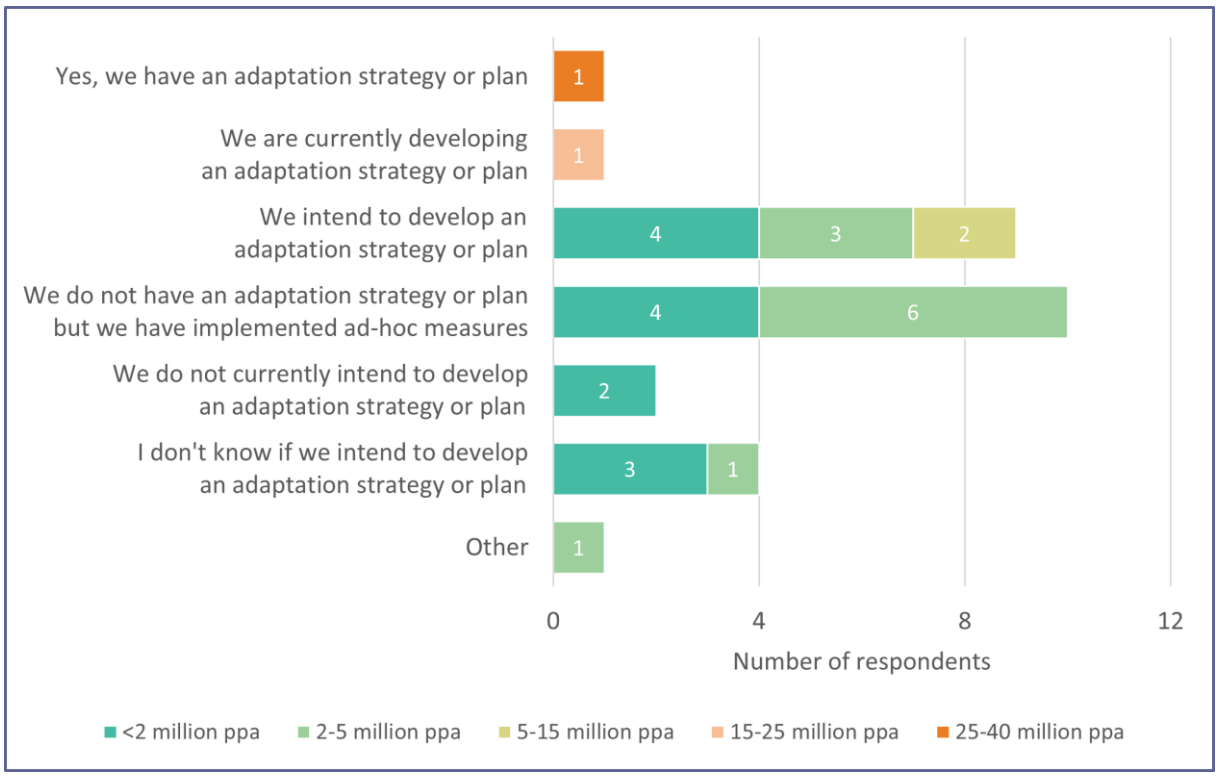

Figure 30 *Respondents' climate adaptation strategy status (n=28)*

5.3 Support for climate change risk assessment

The need for guidance and data are the biggest challenges for airports carrying out a climate change risk assessment.

Airports that have already carried out, are in the process of carrying out, or are planning a climate change risk assessment, cited lack of guidance and data as the biggest challenges they faced or anticipated. Financial and human resources were the second and third biggest challenges (**Figure 31**). In particular, the need for methodologies, examples of good practices, completed risk assessments and case studies was noted. Acquiring suitable data or projections of climate effects was also cited as a challenge.

Some airports that have already carried out a risk assessment used a consultancy or had government or aid agency support. However, this may not be a possibility for all airports, so it is essential that they have access to sufficient guidance so as to carry out a risk assessment autonomously if required. One airport planning a risk assessment cited the need to prioritise other factors over climate change risk analysis as a challenge. One airport that has completed a risk assessment noted that although they have support from middle managers, more commitment from top management was required. The airport that did not face any challenges noted that the study was carried out as a government initiative for the transport sector with funding from an overseas aid agency.

Similarly, for those that are not currently planning a risk assessment, or don't know if one is planned, guidance and methodologies, examples and case studies and, in particular, data were identified as the support which airports viewed as being most valuable and necessary if they were to process with an assessment. This was a view held by 9/10 respondents that answered the question. Just one respondent was not yet sure what information of guidance would be necessary.

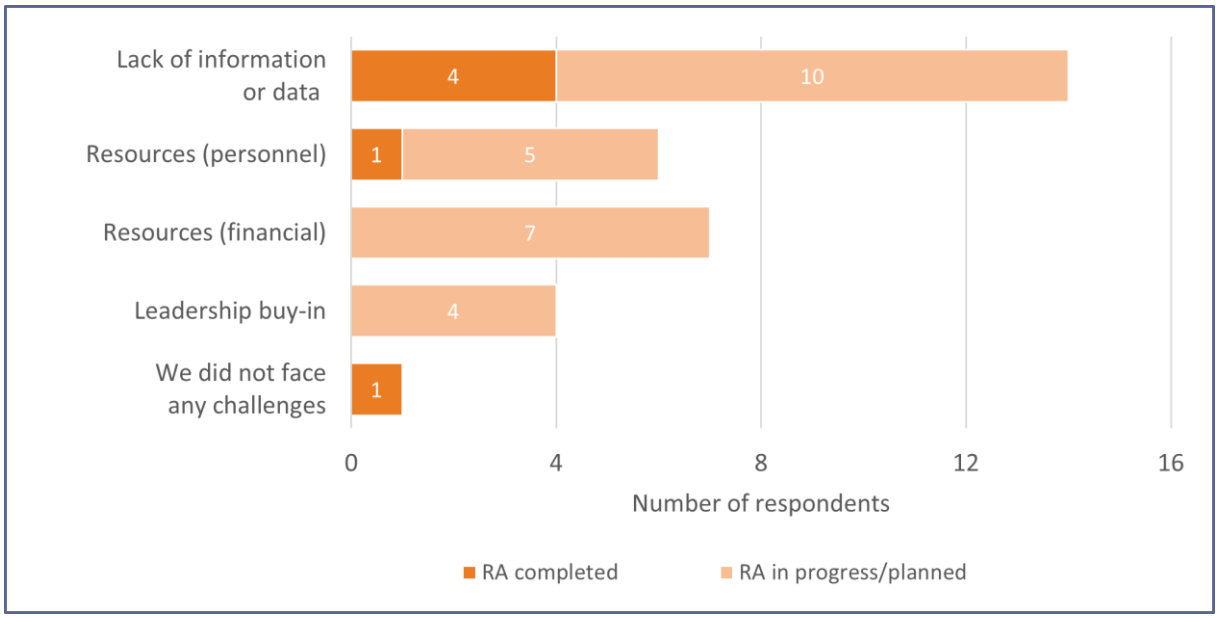

Figure 31 *Challenges faced or anticipated when carrying out or planning a risk assessment (RA) (n=16)*

5.4 Adaptation measures

Survey respondents are implementing a range of adaptation measures to reduce the risks from impacts such as flooding, water scarcity and higher temperatures. Low-carbon resilience measures are being implemented to promote energy security and efficiency.

Survey respondents are implementing infrastructure, operational, health and economic adaptation and resilience measures to prepare their airports for the impacts of climate change (**Figure 32**).

Flooding is the impact which survey respondents expect to be the biggest challenge and 12 survey respondents are already implementing measures to reduce flooding impact. Measures being implemented include pumps to remove flood water, elevation of flood prone zones, reconfiguration of storm channels and increasing drainage capacity. Periodic inspection and maintenance were also cited as important to reduce risk.

Water scarcity is considered the second biggest challenge for respondents, with several implementing measures to improve water efficiency and increase water security. The main measures being taken include rainwater capture and reuse and measures to reduce consumption of potable water.

Other adaptation measures include natural ventilation to increase cooling capability, operational measures for adverse weather, wildlife management measures such as fauna control to reduce risk of bird strikes, and safety measures such as implementing lightning rods. Having contingency plans in place and preparing personnel to deal with disruptive events were also cited as important measures.

Low-carbon resilience measures to increase energy security and efficiency are a win-win option, both making an airport more resilient to disruptions to energy supply and reducing emissions. Measures being taken include transitioning to renewable and self-generated energy-sources such as solar, improvements in cooling systems to make them both more effective and more energy efficient, and measures to reduce and optimise energy consumption such as intelligent building management systems.

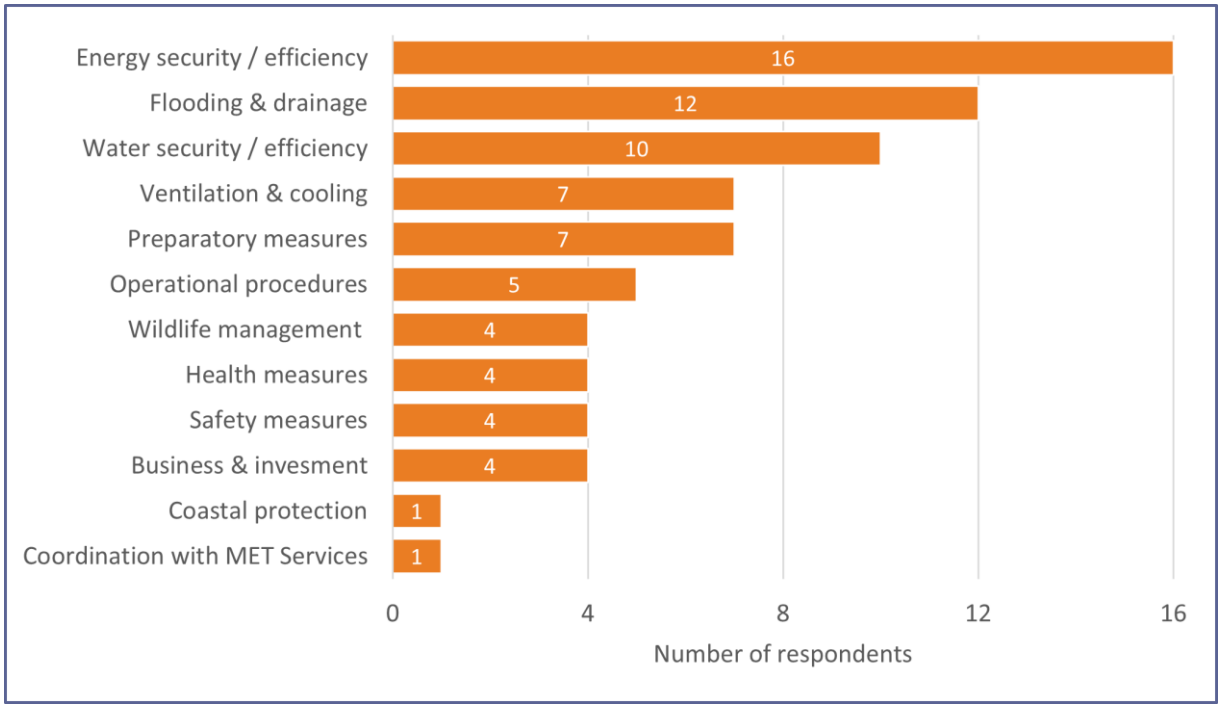

Figure 32 *Adaptation measures being implemented by survey respondents (n=22)*

5.5 LAC Airports' level of preparedness for the impacts of climate change

Seventy-six percent of survey respondents consider their airport slightly prepared or moderately prepared to deal with the impacts of climate change, while just 21% consider their airport well- or very-well prepared.

Survey respondents were asked whether they think their airport is well-prepared to deal with the impacts of climate change (**Figure 33**).

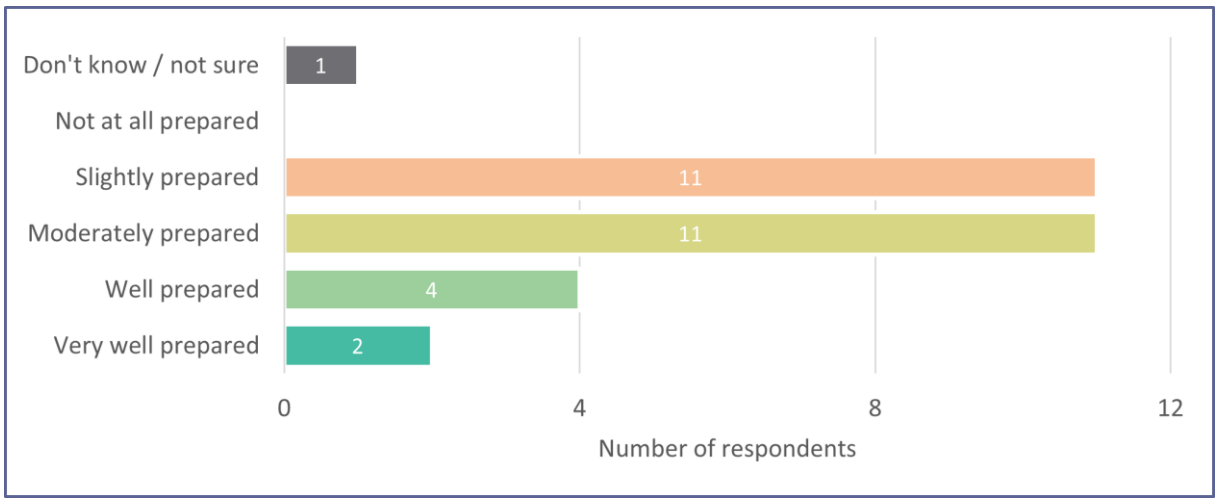

Figure 33 *Level of preparedness of LAC airports for the impacts of climate change (n=29)*

Eleven out of twenty-nine (38%) of respondents stated that their airport is slightly prepared and 11/29 (38%) moderately prepared. Four out of twenty-nine (14%) respondents stated that their airport is well-prepared and 2/29 (7%) that their airport is very well-prepared. No airports answered that they were not at all prepared, but one answered don't know. This indicates that airports in the region are starting to adapt and build resilience to the potential impacts of climate change ahead but that increased and accelerated action is needed.

6. CONCLUSION AND RECOMMENDATIONS

It is clear that the effects of climate change and the resulting impacts are a growing risk for LAC airports. More than 80% of survey respondents are already experiencing the effects of climate change, with some respondents already experiencing up to eight different effects (out of the 11). This indicates that climate change is already a clear and present issue in the region. By 2050, 100% of survey respondents expect to be experiencing at least one effect of climate change with one respondent expecting to be experiencing all eleven effects covered by this study. This clearly demonstrates the growing need for airports to adapt and build resilience to the expected impacts.

Ninety-one percent of survey respondents are already experiencing or expect to experience higher average and extreme temperatures, with 89% experiencing or expecting an increase in precipitation and 83% more frequent or more intense storms. SLR is a specific risk for low-lying coastal airports, but is still already being experienced or is expected by 25/35 (71%) of survey respondents. Although business and economic effects are not an immediate concern for most survey respondents, impacts such as changes in tourism demand, an increase in operating costs and higher insurance premiums are impacts of concern in the future.

Airports across the region are beginning to engage with climate risk assessment and adaptation planning. Although the survey results suggest that more airports are at the stage of engaging with risk assessment rather than the implementation of adaptation plans, it is positive to note that airports are also implementing ad-hoc measures to address specific impacts, thus contributing to raising overall resilience levels in the region. However, while 76% of survey respondents consider their airport slightly prepared or moderately prepared to deal with impacts of climate change, just 21% consider their airport well- or very-well prepared, indicating that further action is needed to augment adaptation and resilience levels at the region's airports.

To increase and accelerate climate change risk assessment and adaptation action in the region, and building on the work already achieved by ACI-LAC, the following five recommendations are proposed:

1. **Continue awareness-raising:** continue and augment current actions to raise awareness of the potential impacts of climate change for the region's airports and the need to take action to adapt.
2. **Coordination and collaboration:** continue and augment current actions to coordinate, collaborate, promote learning and share good practices within the LAC region, with other ACI regions and globally through peer-to-peer support, bilateral meetings, working groups, workshops, conferences and other international fora.
3. **Promote and support climate change risk assessments:** provide information and access to existing guidance on carrying out a climate change risk assessment. Consider development of case studies or examples of airport risk assessments, targeted guidance, access to reliable data and climate projections, and learning opportunities such as workshops.
4. **Promote and support implementation of climate change adaptation and resilience measures:** provide information and access to existing guidance on implementing adaptation measures, plans and strategies. Consider development of case studies or examples of airport climate adaptation measures, targeted guidance, and learning opportunities such as workshops.
5. **Promote and support regionally-focused research:** engage with academia and other research bodies to identify relevant research gaps in the LAC region and promote regionally-focused research on climate change impacts, effects and adaptation measures for the region's airports.

Momentum to adapt the region's airports to the impacts of climate change is growing. However, the effects of climate change and the resulting impacts for airports are also accelerating. We need to act now to increase awareness, promote climate risk assessment and implement adaptation measures so as to achieve a LAC airport sector that is well-adapted and resilient to the impacts of climate change.

7. REGIONAL FOCUS

This section will explore the effects and impacts expected by respondents in each of the IPCC subregions. For a detailed overview of potential impacts and adaptation measures please see the Directory of Climate Impacts and Adaptation Measures in section 8 of this report.

7.1 Central America

Key climate effects

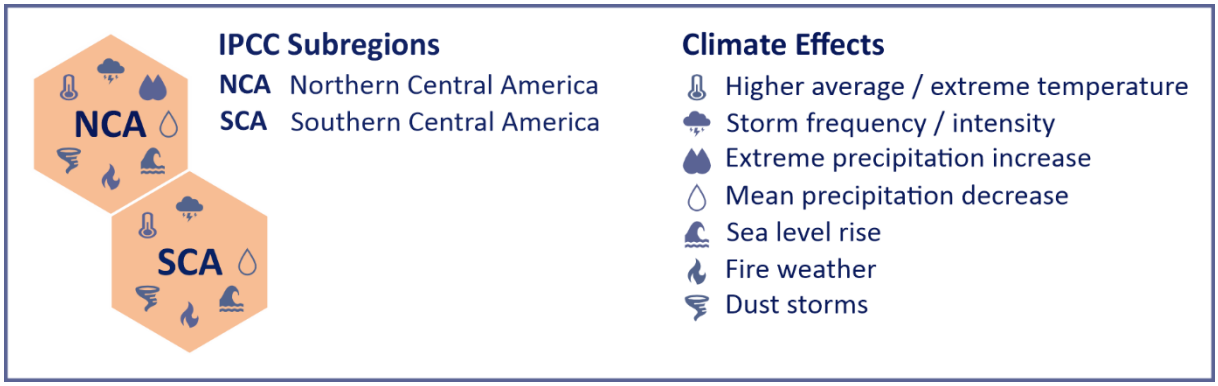

Figure 34 *Key climate effects in Central America*

Central America is comprised of the two IPCC subregions of Northern Central America (NCA) and Southern Central America (SCA). The main climate effects projected are broadly similar across the two subregions with both expecting an increase in average temperatures and extreme heat to continue (**Figure 34**). An increase in fire weather, a combination of hot, dry and windy conditions, is also expected. Both subregions will experience a decrease in mean precipitation and an increase in drought conditions, although NCA may also see an increase in heavy precipitation events. Tropical cyclones are expected to decrease in number but increase in intensity. Relative sea level rise is projected along with coastal flooding and coastal erosion. Severe storms and dust storms are expected to become more extreme. In NCA a decrease in North American monsoon precipitation is projected.

Climate effects expected by survey respondents in Central America

As in the wider LAC region, the main effects which survey respondents are already experiencing or expect to experience in the future are higher average and extreme temperatures, increased precipitation, increased frequency or intensity of storms and sea level rise (**Figure 35**). All respondents are already experiencing higher average and extreme temperatures with three out of four (75%) already experiencing an increase in precipitation and storminess, and the other respondent expecting to be affected by 2030. A decrease in precipitation is also an important effect in the subregion, with three out of four (75%) respondents already experiencing it. Business and economic effects, although currently only being experienced by one respondent, are expected by three out of four (75%) by 2030.

At present, all four respondents in the subregion are already experiencing at least four of the eleven climate effects covered by the survey, with one respondent already experiencing eight effects (**Figure 36**).

By 2030, all four respondents in the subregion are already expecting to experience at least six effects of climate change with one respondent already experiencing ten effects. By 2050, all respondents are expecting to experience at least six effects.

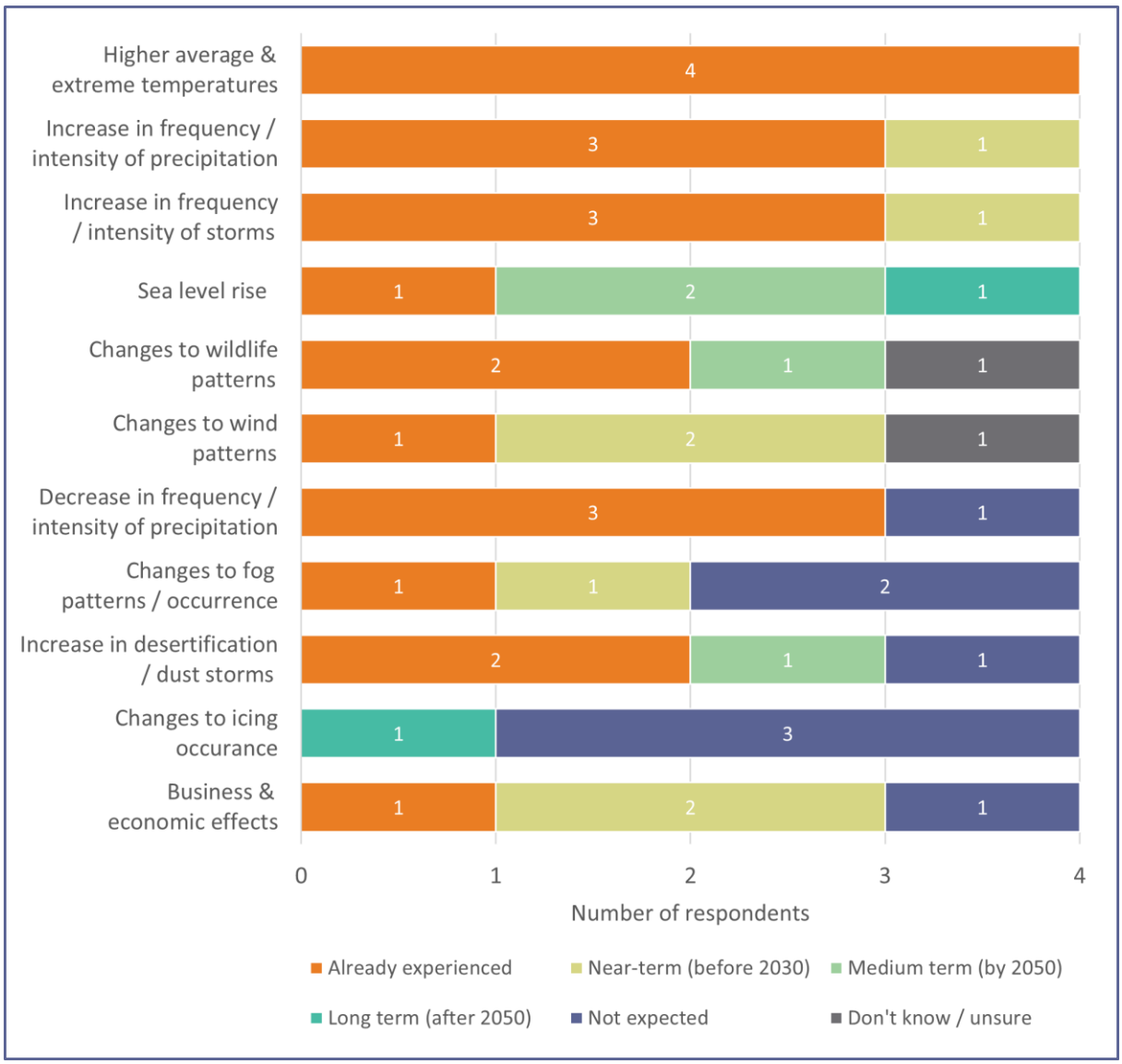

Figure 35 *Climate change effects which regional respondents have experienced or expect to experience in the future (n=4)*

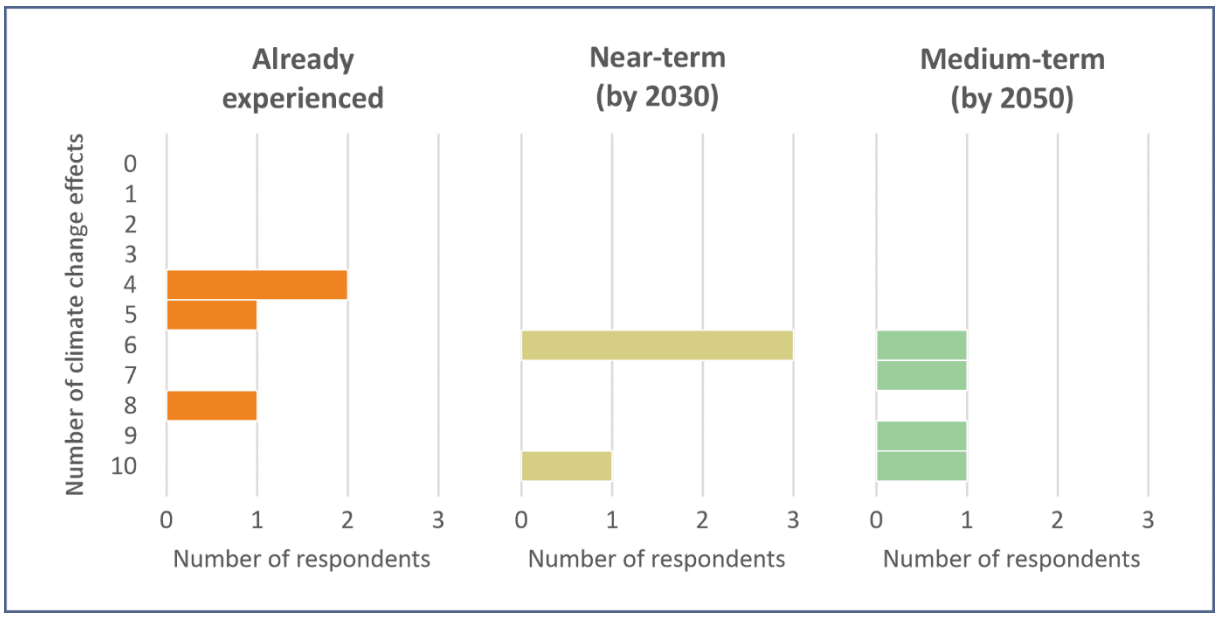

Figure 36 *Number of climate change effects which regional respondents have already experienced or expect to experience in the near to medium term future (n=4)*

Key impacts and adaptation measures

Table 1 identifies some key impacts that airports in NCA and SCA may need to prepare for based on projected climate effects and impacts identified by survey respondents in the subregions.

Projected Effects	Key Impacts	Potential Adaptation Measures
Higher average / extreme temperatures	• An increase in cooling demand • Increased risk of wildfires	• Increase cooling capability / improve natural ventilation • Increase of firefighting capabilities at times of high fire risk
Decrease in precipitation	• Water shortages/restrictions	• Water management plans
Increase in extreme rainfall events	• Flooding of infrastructure • Disruption to operations	• Increase drainage capacity • Operational measures to increase resilience/flexibility e.g. A-CDM
Increase in storm intensity	• Damage to infrastructure • Disruption to operations	• Reinforce infrastructure to withstand stronger winds • Contingency plans for extreme events
Sea level rise	• Temporary flooding of infrastructure • Flooding of ground transportation	• Natural barriers / sea defences • Coordination with ground transport providers

Table 1 *Key impacts and adaptaiton measures in NCA and SCA*

7.2 The Caribbean

Key climate effects

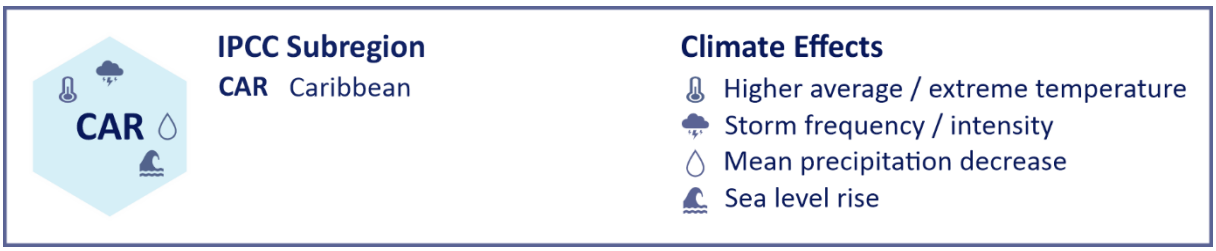

Figure 37 *Key climate effects in the Caribbean*

The Caribbean is already experiencing an increase in mean temperatures, and this is expected to increase along with an increase in extreme heat. A decrease in mean precipitation and an increase in drought conditions is projected (**Figure 37**). An increase in heavy precipitation events has been observed, although whether this will continue in the future is uncertain. Tropical cyclones are expected to decrease in number but increase in intensity. Relative sea level rise is projected along with coastal flooding and coastal erosion. Airports are an important gateway for Caribbean islands to the world. Therefore, it is critical to assess the risks that this vital infrastructure might face due to climate change.

Climate effects expected by survey respondents in the Caribbean

The main effects which survey respondents in the Caribbean are already experiencing or expect to experience in the future are increased precipitation, an increase in frequency or intensity of storms and higher average and extreme temperatures (**Figure 38**). Sea level rise is already being experienced by some airports in the region and expected to be experienced by 9/13 (69%) of respondents overall. Business and economic effects are expected by 10/13 respondents (77%) between now and 2050.

At present, 12/13 (92%) of respondents in the subregion are already experiencing at least one of the eleven effects of climate change covered by the survey, with three respondents already experiencing five and three respondents already experiencing six effects (**Figure 39**). Just one respondent is not yet experiencing any effects of climate change.

By 2030, all respondents in the subregion expect to be experiencing at least one effect of climate change, with 9/13 (69%) expecting to experience at least five effects and two respondents already expecting to experience seven out of the eleven effects. By 2050, six respondents expect to be experiencing at least seven effects with one respondent expecting to experience nine effects.

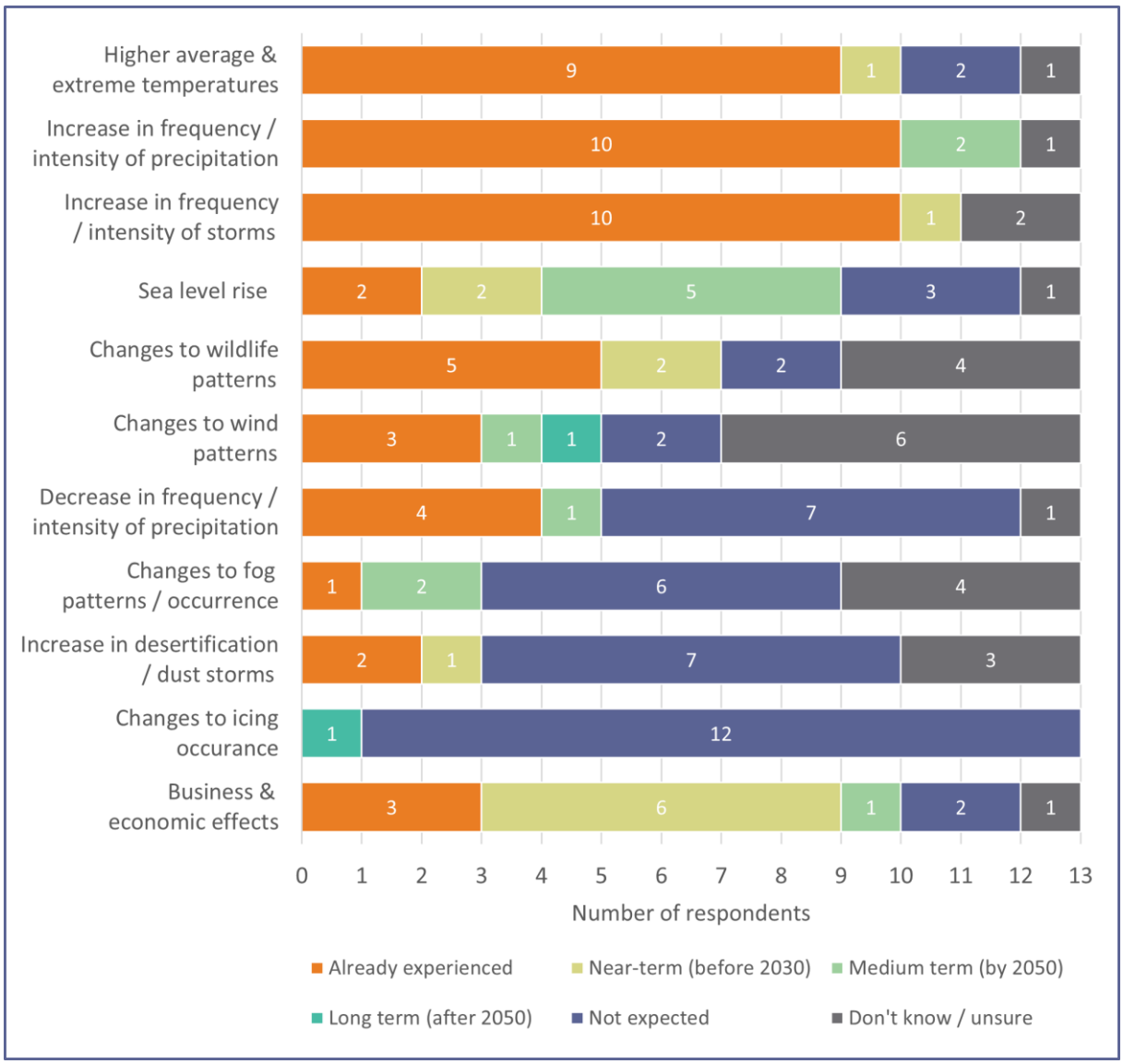

Figure 38 *Climate change effects which regional respondents have experienced or expect to experience in the future (n=13)*

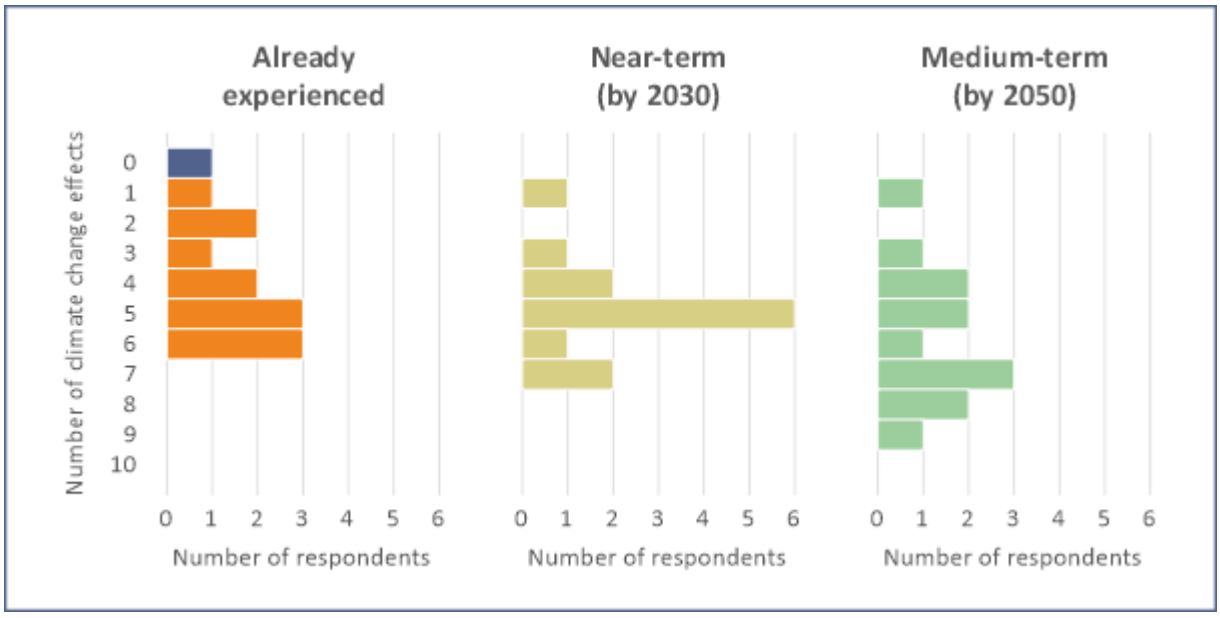

Figure 39 *Number of climate change effects which regional respondents have already experienced or expect to experience in the near to medium term future (n=13)*

Key impacts and adaptation measures

Table 2 identifies some key impacts that airports in CAR may need to prepare for based on projected climate effects and impacts identified by survey respondents in the subregions.

Projected Effects	Key Impacts	Potential Adaptation Measures
Higher average / extreme temperatures	• An increase in cooling demand • Health impacts for passengers/employees	• Increase cooling capability / improve natural ventilation • Cooling and shade for ground workers
Decrease in precipitation	• Water shortages/restrictions	• Water management plans
Increase in storm intensity	• Flooding of infrastructure • Disruption to operations	• Reinforce infrastructure to withstand stronger winds • Contingency plans for extreme events
Sea level rise	• Temporary flooding of infrastructure • Disruption to operations	• Natural barriers / sea defences • Operational measures to increase resilience/flexibility e.g. A-CDM

***Table 2** Key impacts and adaptaiton measures in CAR*

7.3 Northwestern and Southwestern South America

Key climate effects

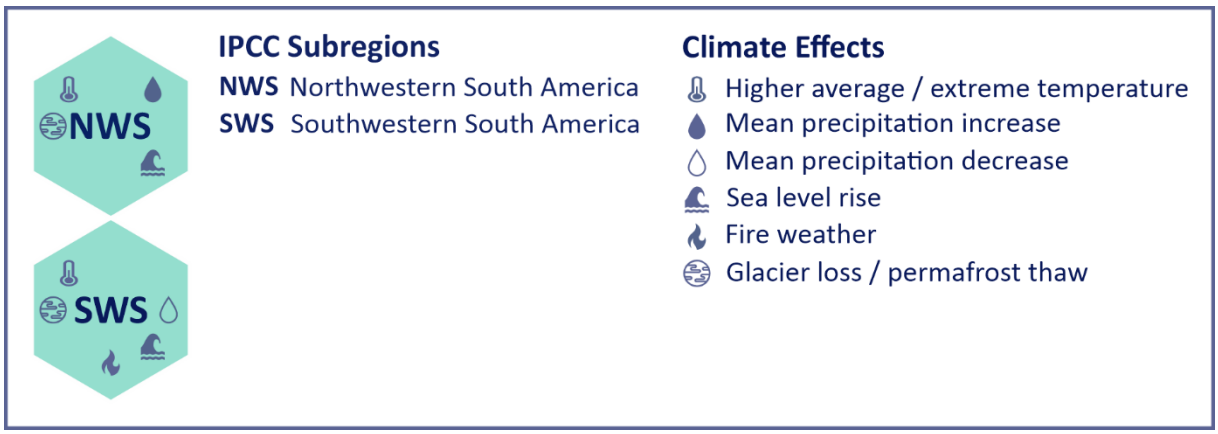

Figure 40 *Key climate effects in NWS and SWS*

The main climate effects projected in Northwestern and Southwestern South America are broadly similar across the two subregions with both expecting an increase in average temperatures and extreme heat to continue (**Figure 40**). Relative sea level rise is projected in both subregions along with coastal flooding and coastal erosion. The main difference between the two subregions is that an increase in mean precipitation is projected in NWS whereas a decease alongside an increase in drought conditions and fire weather is projected in SWS. However, both regions will experience snow, glacier and icesheet loss. In SWS permafrost thaw is also projected.

Climate effects expected by survey respondents in NWS and SWS

All nine survey respondents (100%) in Northwestern and Southwestern South America are already experiencing an increase in higher average extreme temperatures or expect to experience them by 2050 at the latest (**Figure 41**). An increase in precipitation (7/9), sea level rise (6/9) and changes to wildlife patterns (6/9) are the other main effects which respondents expect to experience. The effect which most respondents are already experiencing is changes to fog patterns (4/9, all from NWS). Business and economic effects, although currently only being experienced by one respondent, are expected by five out of nine by 2030.

At present, 6/9 (67%) of respondents in the subregion are already experiencing at least two of the eleven climate change effects, with one respondent already experiencing six effects (**Figure 42**). Three respondents are yet to experience any effects of climate change.

By 2030, all respondents expect to be experiencing at least two effects of climate change, with four respondents expecting to experience four effects and one respondent expecting to experience seven effects. By 2050, all respondents expect to be experiencing at least four effects of climate change with two respondents expecting to experience seven effects.

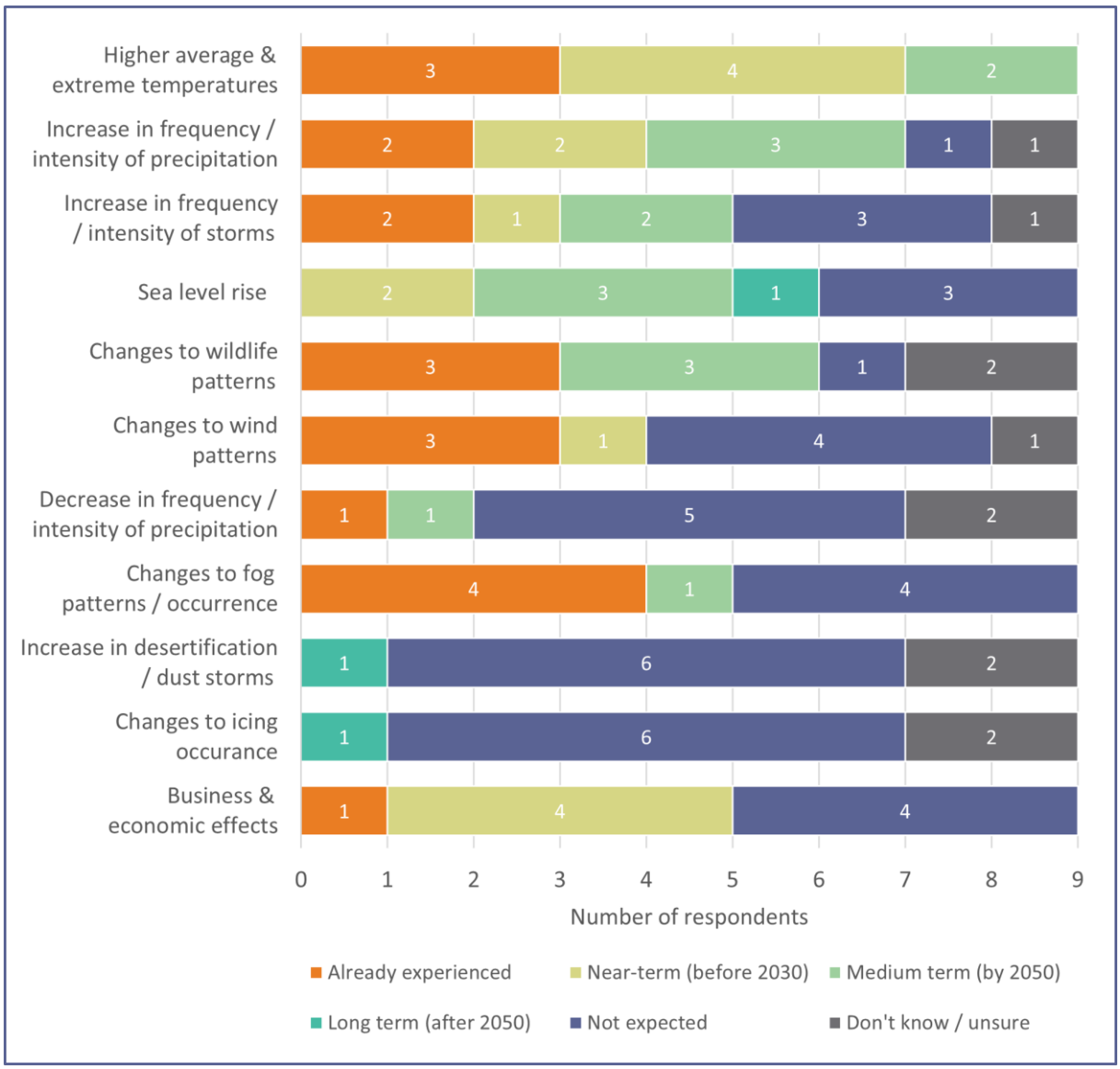

Figure 41 *Climate change effects which regional respondents have experienced or expect to experience in the future (n=9)*

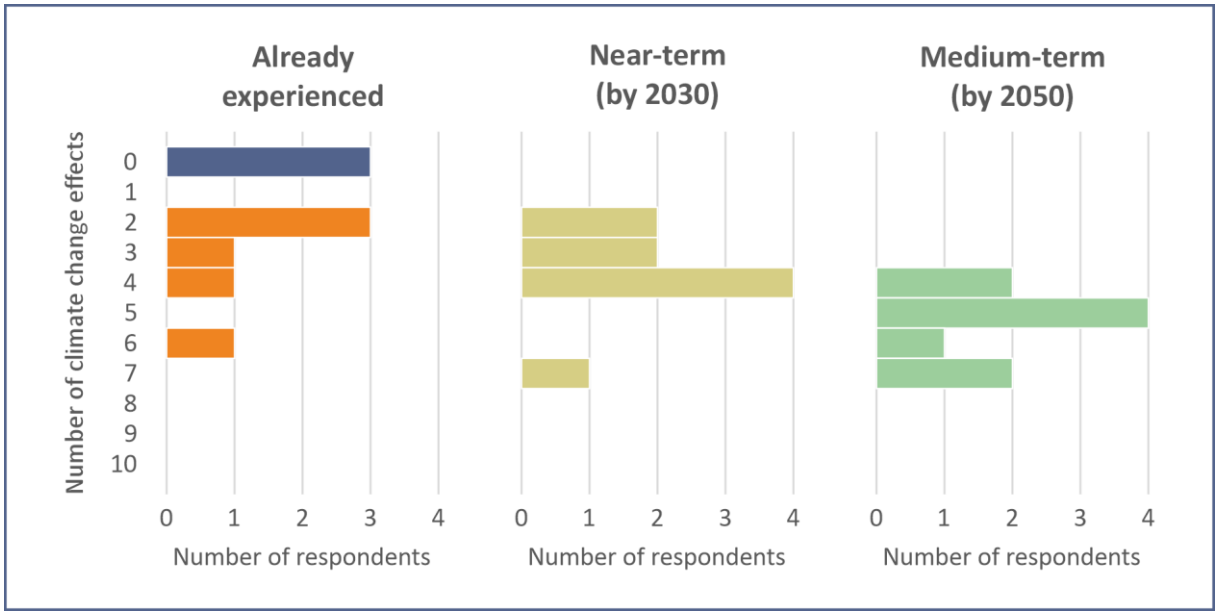

Figure 42 *Number of climate change effects which regional respondents have already experienced or expect to experience in the near to medium term future (n=9)*

Key impacts and adaptation measures

Table 3 identifies some key impacts that airports in NWS and SWS may need to prepare for based on projected climate effects and impacts identified by survey respondents in the subregions.

Projected Effects	Key Impacts	Potential Adaptation Measures
Higher average / extreme temperatures	• An increase in cooling demand • Health impacts for passengers/employees	• Increase cooling capability / improve natural ventilation • Cooling and shade for ground workers
Increase in frequency / intensity of precipitation	• Flooding of infrastructure • Disruption to operations	• Increase drainage capacity • Operational measures to increase resilience/flexibility e.g. A-CDM
Changes to wildlife patterns	• Changes in wildlife migration patterns • Increase in bird strikes	• Wildlife monitoring/ management programmes • Bird control measures
Changes to fog patterns	• Increase in fog occurrence impacting operations	• Low visibility procedures/measures

Table 3 *Key impacts and adaptaiton measures in NWS and SWS*

7.4 Northern, Eastern and Southeastern South America

Key climate effects

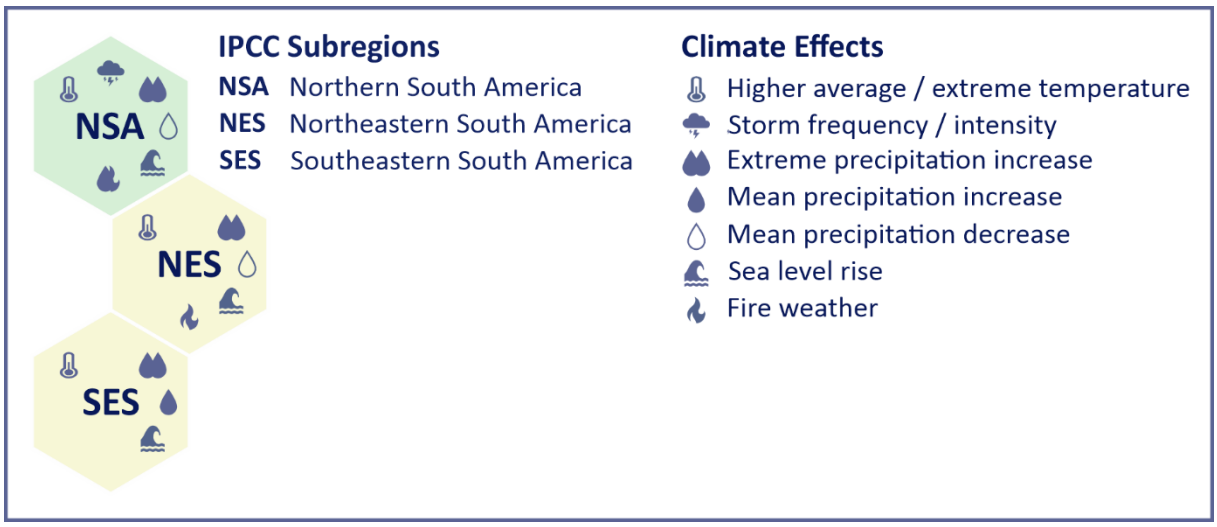

Figure 43 *Key climate effects in NSA, NES and SES*

The main climate effects projected in Northern South America, Northeastern South America and Southern are broadly similar across the three subregions with all three expecting an increase in average temperatures and extreme heat to continue (**Figure 43**). Relative sea level rise is projected in all three subregions along with coastal flooding and coastal erosion.

The main difference between the three subregions is that an increase in mean precipitation is projected in SES, whereas a decrease in mean precipitation alongside an increase in drought conditions and fire weather is projected is projected in NSA and NES. Both NES and SES are projected to experience an increase in heavy precipitation events. In NSA, tropical cyclones are expected to decrease in number but increase in intensity.

Climate effects expected by survey respondents in NSA, NES and SES

All nine survey respondents (100%) in NSA, NES and SES and Southwestern South America are already experiencing an increase in higher average extreme temperatures or expect to experience them in the future (**Figure 44**). An increase in frequency or intensity of storms (9/9), an increase in precipitation (8/9) sea level rise (6/9) and a decrease in precipitation (6/9) are the other main effects which respondents expect to experience. The effects which most respondents are already experiencing are higher average or extreme temperatures (5/9) an increase in precipitation (5/9) and an increase in frequency or intensity of storms (5/9).

At present, 7/9 (78%) of respondents in the subregion are already experiencing at least one of the eleven climate change effects, with one respondent already experiencing six effects (**Figure 45**). Two respondents are yet to experience any effects of climate change.

By 2030, all except one of the respondents expect to be experiencing at least three effects of climate change, with three respondents expecting to experience four effects and three respondents expecting to experience six effects. By 2050, all respondents expect to be experiencing at least two effects of climate change with one respondent expecting to experience eight effects.

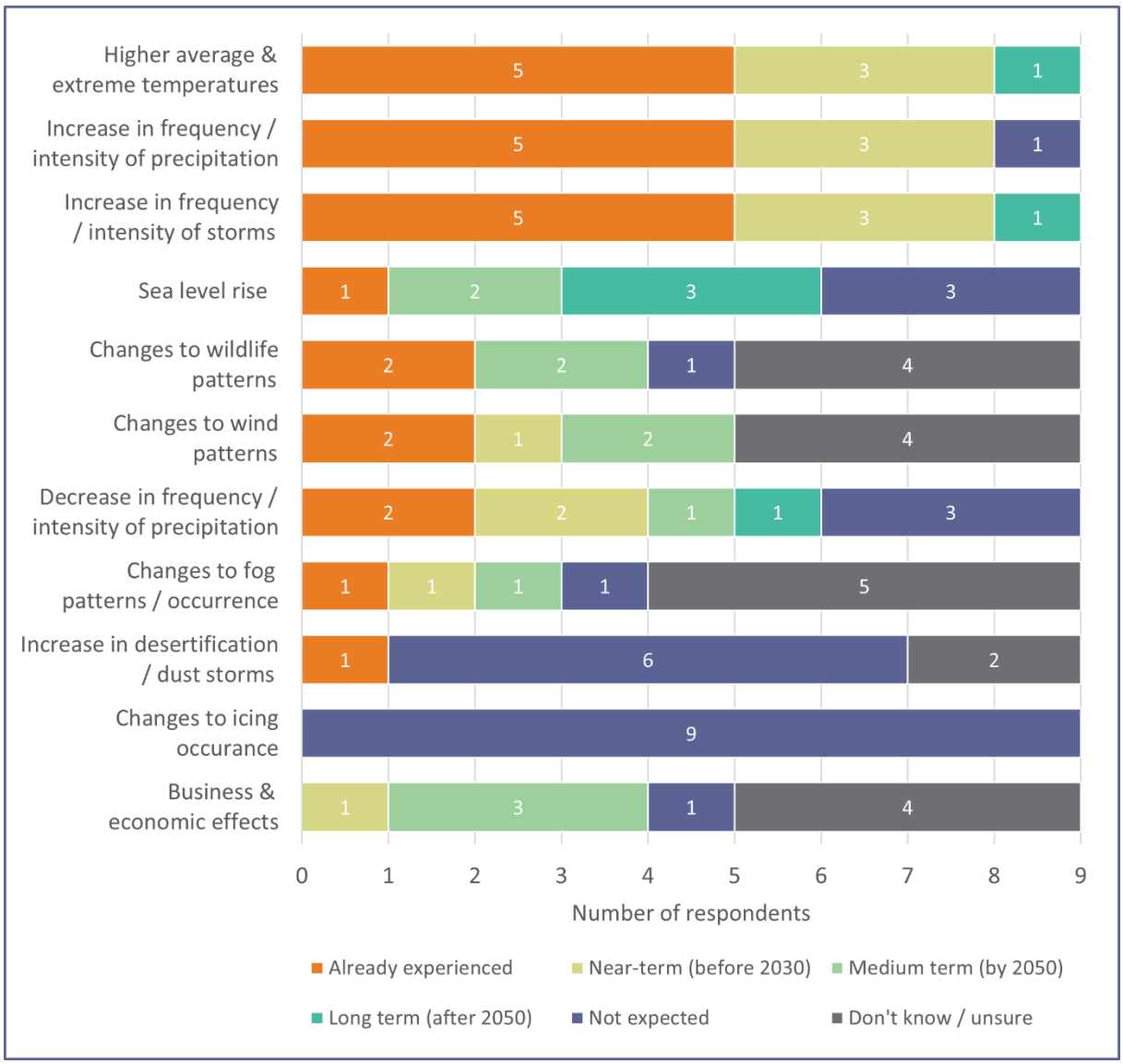

Figure 44 *Climate change effects which regional respondents have experienced or expect to experience in the future (n=9)*

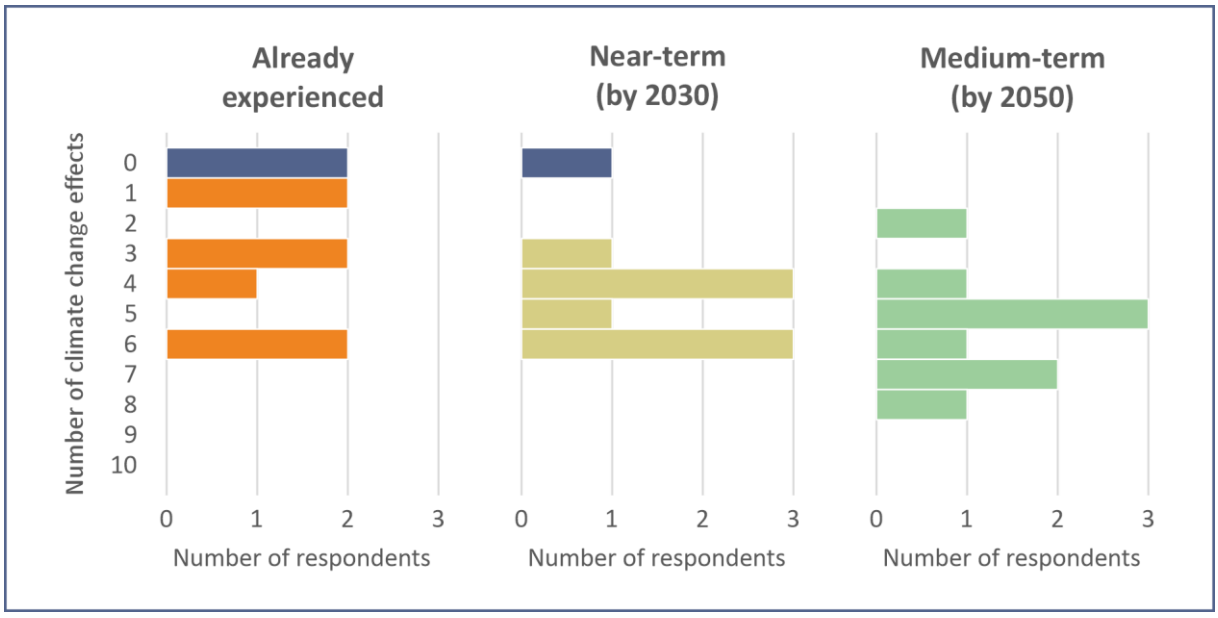

Figure 45 *Number of climate change effects which regional respondents have already experienced or expect to experience in the near to medium term future (n=9)*

Key impacts and adaptation measures

Table 4 identifies some key impacts that airports in NSA, NES and SES may need to prepare for based on projected climate effects and impacts identified by survey respondents in the subregions.

Projected Effects	Key Impacts	Potential Adaptation Measures
Higher average / extreme temperatures	• An increase in cooling demand • Health impacts for passengers/employees	• Increase cooling capability / improve natural ventilation • Cooling and shade for ground workers
Increase in average / extreme precipitation	• Flooding of infrastructure • Disruption to operations	• Increase drainage capacity • Operational measures to increase resilience/flexibility e.g. A-CDM
Decrease in precipitation	• Water shortages/restrictions	• Water management plans
Increase in storm intensity	• Damage to infrastructure • Disruption to operations	• Reinforce infrastructure to withstand stronger winds • Contingency plans for extreme events
Sea level rise	• Temporary flooding of infrastructure • Flooding of ground transportation	• Natural barriers / sea defences • Coordination with ground transport providers

Table 4 *Key impacts and adaptaiton measures in NSA, NES and SES*

8. DIRECTORY OF CLIMATE IMPACTS & ADAPTATION MEASURES

This directory provides an overview of potential climate impacts that may be experienced in the 10 LAC subregions, and possible adaptation and resilience measures to address them. Please note that:

- The subregions identified for each effect are those where it is projected to occur by the IPCC. However, even within subregions there can be differences in effects and impacts, and different impacts for the same effect. Effects and impacts may also occur outside of the subregions where they are projected. Therefore, airports are strongly advised to carry-out their own climate change risk assessments to identify the effects and impacts they themselves are most at risk of.
- Some effects are not covered at subregion level by the IPCC. In this case it is noted that no subregional information is available.
- The adaptation measures listed are not mapped to specific impacts as 1) an adaptation measure may be suitable for addressing more than one impact, 2) to avoid being too prescriptive as other adaptation measures not listed may be possible or become available in the future and 3) it is strongly advised that airports identify adaptation measures to implement based on the results of a climate change risk assessment: those listed in the directory are intended to provide an indication only.
- Cross-cutting measures such as training of personnel and communication with MET providers are essential for all effects. It is also important to coordinate with external parties such as ground transport providers and utilities providers on measures for maintaining services during disruption.

8.1 Higher average and extreme temperatures

Subregions: All subregions

Key Impacts	Potential Adaptation Measures
• An increase in cooling demand for infrastructure • Heat damage to infrastructure e.g. pavement melting • Health impacts (heat stress) for employees and passengers • Overheating of electrical equipment • Increase in fire risk at airports e.g. from fuel • Increased risk of wildfires • Impacts to aircraft take-off performance • Disruption to ground transport due to overheating • Damage/destabilization of infrastructure such as runways, roads, buildings due to permafrost thaw (SWS, SSA)	• Increase cooling capability / improve natural ventilation • Cooling measures e.g. Air curtains at entrances, tinting/membranes on glass windows/thermoacoustic glass facades • Cooling and shade for ground workers; protective equipment (e.g. hats, clothing), good hydration and more frequent breaks. • Cool runways with recycled water • Increase cooling for sensitive electrical infrastructure • Auxiliary power sources, back-up air conditioning units for operationally critical functions. • Increase vegetation such as green roofs • Analysis to understand how aircraft take-off performance might change • Schedule departure of heavier aircraft for cooler times of day (noting potential changes to noise impacts) • Check surface materials for runways etc can withstand higher temperatures • Pruning and removal of dry vegetation to reduce fire risk • Increase of firefighting capabilities at times of high fire risk • Reinforcement of infrastructure to counter permafrost thaw (SWS, SSA)

8.2 An increase in frequency/intensity precipitation (average/extreme)

Subregions: NCA, NWS, NSA, SAM, NES, SES, SSA

Key Impacts	Potential Adaptation Measures
• Flooding of infrastructure such as airport terminals and runways • Disruption to operations (delays, diversions, cancellations) • Safety risks/delays to passengers boarding/disembarking • Low visibility conditions • Deterioration in ground handling conditions • Inundation of pollution control systems/ contamination of groundwater or local water courses • Flooding of ground transport	• Increase drainage capacity of buildings and runways/taxiways • Runway surface condition reporting (ICAO Global Reporting Format) • Regular maintenance of drainage capacity • Water pumps to remove excess water • Elevation of flood-prone zones • Planning for movement of people, cargo and vehicles along alternative/higher routes in the event of flooding • Rainwater collection systems • Operational measures to increase resilience and flexibility such as Airport CDM (A-CDM) • Increase vegetation such as green roofs • Replace asphalt with porous surfaces such as soil • Low visibility procedures/measures e.g. ground based augmentation system (GBAS), Surface Movement Radar

8.3 An increase in frequency/intensity of storms

Subregions: NCA, SCA, CAR, NSA

Key Impacts	Potential Adaptation Measures
• Damage to infrastructure such as airport terminals • Flooding of infrastructure from heavy precipitation or storm surge • Disruption to operations (delays, diversions, cancellations) • Safety risks/delays to passengers boarding/disembarking • Passenger disruption due to delayed/cancelled flights • Deterioration in ground handling conditions/safety risks for personnel • An increase in lightning strikes • Disruption to ground transport • Disruption to power and communication services	• Contingency plans for extreme events: early warning systems, emergency management plans, local/regional support networks (e.g. for back-up communications, power) • Regular practice of contingency/emergency plans • Coordination with airlines on plans for evacuation of passengers/citizens before extreme events • Reinforce existing infrastructure to withstand stronger winds • Design new infrastructure to withstand stronger winds • Increase drainage capacity of buildings and runways/taxiways • Operational measures to increase resilience and flexibility such as Airport CDM (A-CDM) • Runway surface condition reporting (ICAO Global Reporting Format) • Increase in staff and supplies (food, water, energy) to deal with increase in passengers due to delays/ cancellations/diversions. • Work with airlines to support passenger welfare, onward transportation, and re-bookings • Nature-based solutions such as mangrove and wetlands to reduce wind speeds • Back-up power supplies e.g. generators • Protection of sensitive IT and electrical equipment • Lightning detection systems and lightning protection shelters

8.4 Sea level rise

Subregions: NCA, SCA, CAR, NWS, NSA, NES, SES, SWS, SSA

Key Impacts	Potential Adaptation Measures
• Temporary flooding of infrastructure such as airport terminals and runways • Permanent flooding of infrastructure such as airport terminals and runways • Disruption to operations (delays, diversions, cancellations) • Rising groundwater tables increasing risk of flooding • Flooding of ground transport	• Allow a safe amount of inundation • Increased drainage capacity • Water pumps • Natural barriers e.g. vegetation, mangrove and trees • Sea defences e.g. levees, boulders or walls • Raising infrastructure and equipment above inundation levels • Reinforcing infrastructure and equipment e.g. with salt-water resistant materials or sealants • Airport relocation

8.5 Changes to wildlife patterns

Subregions: All subregions

Key Impacts	Potential Adaptation Measures
• Changes in wildlife migration patterns e.g. increase in migratory birds • An increase in bird strikes • Changes to vegetation • Increase in bird populations at airport • Increase in invasive species • Damage to landscaping / increase in maintenance costs	• Wildlife monitoring and management programmes • Biodiversity protection and implementation programmes e.g. for mangrove • Bird control programmes • Temporary alteration of flight paths to avoid migrating birds • Changes in land management practices to deter wildlife • Permanent removal / regular uprooting of unwanted vegetation.

8.6 Changes in wind patterns

Subregions: C & S America - increase in wind speed (except SSA); CAR - limited data

Key Impacts	Potential Adaptation Measures
• Wind damage to infrastructure, equipment and aircraft • Disruption to operations due to strong winds (delays, diversions, cancellations) • Deviations from prevailing wind and/or an increase in crosswinds impacting operations • Changes to noise impact due to wind-driven changes to arrival/departure routes/procedures • Safety risks for personnel • Safety risks/delays to passengers boarding/disembarking • Impacts on take-off performance due to reduction in wind speed	• Reinforcement of infrastructure / regular maintenance • Update of design standards for more extreme wind conditions • Projections of changes to local wind conditions • Operational measures to increase resilience and flexibility such as Airport CDM (A-CDM) • Integrate wind speed changes into analyses of changes to take-off performance due to higher temperatures

8.7 Decrease in frequency / intensity of precipitation

Subregions: NCA, SCA, CAR, NSA, NES, SWS

Key Impacts	Potential Adaptation Measures
• Water shortages and restrictions • Damage to infrastructure due to shrinking of clay	• Water management plans to reduce water consumption / counter water shortages and drought • Water storage measures • Rainwater collection systems • Water treatment and water reuse for non-potable uses

8.8 Changes in fog patterns / occurrence

Subregions: No subregional information

Key Impacts	Potential Adaptation Measures
• An increase in fog occurrence impacting operations (visibility, delays, cancellations) • A decrease in fog occurrence reducing operational impacts (visibility, delays, cancellations)	• Low visibility procedures/measures e.g. ground based augmentation system (GBAS), Surface Movement Radar • Operational measures to increase resilience and flexibility such as Airport CDM (A-CDM) • Improved forecasting of fog occurrence

8.9 Increase in desertification / dust storms

Subregions: Desertification - no subregional information; Dust storms - NCA, SCA

Key Impacts	Potential Adaptation Measures
• An increase in dust storms or sandstorms impacting operations (visibility, delays, cancellations) • Increase in dust storms or sandstorms damaging equipment and aircraft on stands • Encroachment of desert sand on airport • Sand erosion of runway and apron • Increase in maintenance costs • Water shortages	• Operational measures to increase resilience and flexibility such as Airport CDM (A-CDM) • Regular maintenance • Design windbreaks to reduce dust and sand • Trees and vegetation that require little water (and do not attract wildlife) • Water management / recycled water for irrigation

8.10 Changes in icing occurrence

Subregions: No subregional information

Key Impacts	Potential Adaptation Measures
• An increase in de-icing requirements • Delays due to aircraft de-icing • Pollution due to de-icing run-off • Freeze-thaw damage to infrastructure • A decrease in de-icing requirements	• Alternative icing reduction and de-icing methods e.g. infra-red technology, air heaters, anti-icing agents • Increase de-icing run-off capacity • Protect infrastructure from freeze-thaw damage

8.11 Business and economic effects

Subregions: All subregions

Key Impacts	Potential Adaptation Measures
• Climate-change driven changes in traffic/tourism demand • Revenue losses and/or increased operating costs • Costs of airport closure due to disruptive or extreme weather events • Increased energy requirements and costs • An increase in insurance premiums • Costs for additional firefighting services • Costs for increased wildlife management measures • An increase in costs for repairs (airfield surfaces, infrastructure, access roads, etc.) • Staff absenteeism due ill health (heat) or injuries (extreme weather) • New training requirements	• Update airport business planning based on analysis of potential business and economic impacts • Cost benefit analysis to support infrastructure decisions such as retro-fitting, redesign or relocation • Analysis of costs versus level of resilience and criticality • Preventative measures such as reinforcing infrastructure to reduce future damages and costs • Preventative maintenance to reduce potential damages and costs • Measures to reduce costs of operational disruption e.g. A-CDM, augmented low visibility procedures such as GBAS, improved MET forecasting capabilities • Awareness raising, information sharing and training for personnel • Reduction in water consumption • Reduction in energy consumption/improved energy efficiency/ self-generation of energy e.g. solar panels

9. RESOURCES

The following list of resources provide materials which can support airports in carrying out climate change risk assessments and implementing adaptation measures.

Airport Cooperative Research Programme Synthesis (ACRP) 33: Airport Climate Adaptation and Resilience, Transportation Research Board of the National Academies, Washington, D.C., (2012). http://www.trb.org/Publications/Blurbs/167238.aspx

ACRP Synthesis 147: Climate Change Adaptation Planning: Risk Assessment for Airports, Transportation Research Board of the National Academies, Washington, D.C. (2014). http://www.trb.org/Main/Blurbs/173554.aspx

ACRP Synthesis 188: Using Existing Airport Management Systems to Manage Climate Risk, Transportation Research Board of the National Academies, Washington, D.C. (2018). https://www.nap.edu/catalog/25327/using-existing-airport-management-systems-to-manage-climate-risk

ACRP Synthesis 199: Climate Resilience and Benefit-Cost Analysis: a Handbook for Airports, Transportation Research Board of the National Academies, Washington, D.C. (2019). https://www.nap.edu/catalog/25497/climate-resilience-and-benefit-cost-analysis-a-handbook-for-airports

Airports Council International (ACI) Policy Brief: Airports' Resilience and Adaptation to Climate Change (2018). https://store.aci.aero/wp-content/uploads/2018/10/Policy_brief_airports_adaption_climate_change_V6_WEB.pdf

Burbidge, R., Paling, C. and Dunk, R: A Systematic Review of Adaptation to Climate Change in the Aviation Sector, Transport Reviews, (2023). DOI: 10.1080/01441647.2023.2220917 https://www.tandfonline.com/doi/full/10.1080/01441647.2023.2220917

EUROCONTROL Challenges of Growth 2018 Annex 2: Adapting Aviation to a Changing Climate (2018) https://www.eurocontrol.int/sites/default/files/publication/files/challenges-of-growth-annex-2-01102018.pdf

EUROCONTROL-ACI-EUROPE: Aviation Preparations for Summer Adverse Weather (2023) https://www.eurocontrol.int/publication/aviation-preparations-summer-adverse-weather

EUROCONTROL-ACI-EUROPE: Aviation Preparations for Winter Adverse Weather (2023) https://www.eurocontrol.int/publication/aviation-preparations-winter-2023-adverse-weather

ICAO 2018 Climate Change Adaptation Synthesis Report (2020). https://www.icao.int/environmental-protection/Pages/Climate-Adaptation.aspx

ICAO Airport Planning Manual Part II – Land Use and Environmental Management (Doc 9184 – Part 2) (2018). https://store.icao.int/en/airport-planning-manual-land-use-and-environmental-management-doc-9184-part-2

ICAO Eco-Airport Tool kit: Climate Resilient Airports (2020). https://www.icao.int/environmental-protection/Documents/Climate%20resilient%20airports.pdf

ICAO Climate Change Risk Assessment, Adaptation and Resilience (2022) https://www.icao.int/environmental-protection/Pages/Climate-Change-Climate-Risk-Assessment,-Adaptation-and-Resilience.aspx

ICAO Key Steps for Aviation Organisation Climate Change Risk Assessment and Adaptation Planning (2022) https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Key%20Steps%20Risk%20Assessment_final.pdf

ICAO Key Climate Change Vulnerabilities for Aviation Organisations (2022) https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Key%20Vulnerabilities_final.pdf

ICAO Menu of Adaptation Options (2022) https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Menu%20of%20Adaptation%20Measures_final.pdf

International Organization for Standardization (ISO) 14090 Adaptation to Climate Change: Principles, Requirements and Guidance (2019). https://www.iso.org/standard/68507.html

International Transport Forum (ITF) Adapting Transport Infrastructure to Climate Change (2015). http://www.itf-oecd.org/adapting-transport-infrastructure-climate-change

IPCC WG1 Central and South America Factsheet (2021).
https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Central_and_South_America.pdf

IPCC WG1 North and Central America Factsheet (2021).
https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_North_and_Central_America.pdf

IPCC WG1 Small Islands Factsheet (2021).
https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Small_Islands.pdf

United Nations Conference on Trade and Development (UNCTAD): Climate Risk and Vulnerability Assessment Framework for Caribbean Coastal Transport Infrastructure (2018).
https://unctad.org/en/PublicationsLibrary/dtltlb2018d1_en.pdf

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Burbidge, R., Paling, C. and Dunk, R: A Systematic Review of Adaptation to Climate Change in the Aviation Sector, Transport Reviews, (2023). DOI: 10.1080/01441647.2023.2220917 https://www.tandfonline.com/doi/full/10.1080/01441647.2023.2220917

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EUROCONTROL-ACI-EUROPE: Aviation Preparations for Winter Adverse Weather (2023) https://www.eurocontrol.int/publication/aviation-preparations-winter-2023-adverse-weather

ICAO: 2018 Climate Change Adaptation Synthesis Report (2020). https://www.icao.int/environmental-protection/Pages/Climate-Adaptation.aspx

ICAO: Key Steps for Aviation Organisation Climate Change Risk Assessment and Adaptation Planning (2022) https://www.icao.int/environmental-protection/Documents/Climate%20Risk%20Assessment%20and%20Adaptation%20Report_Key%20Steps%20Risk%20Assessment_final.pdf

IPCC: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2021). https://www.ipcc.ch/report/ar6/wg1/

IPCC: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022). https://www.ipcc.ch/report/ar6/wg2/

IPCC: Climate Change Information for Regional Impacts and for Risk assessment. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2021). https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter12.pdf