

# Climate Change: Climate Risk Assessment, Adaptation and Resilience

Key Climate Change  
Vulnerabilities for  
Aviation Organisations

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TABLE OF CONTENTS

Key Climate Change Vulnerabilities for Aviation Organisations.....2  
Introduction .....2  
Small Island Developing States .....2  
Potential effects from four main climate impacts to aviation risk categories .....3



## Key Climate Change Vulnerabilities for Aviation Organisations

### Introduction

The survey of global aviation stakeholders in the 2020 ICAO Climate Adaptation Synthesis identified Higher Average and Extreme Temperatures, Changing Precipitation, Increased Intensity of Storms and Sea Level Rise as the climate impacts which they expect to be most impacted by. The potential effects of these impacts are varied and numerous, and include operational, infrastructure, economic and safety effects. However, the potential effects will vary according to the type of aviation sector organisation and its individual characteristics. Therefore, it is vital for each organisation to carry out a climate change risk assessment and prepare an adaptation plan (see *Keys Steps in Climate Change Risk Assessment and Adaptation Planning for Aviation Organisations*).

The tables below provide an overview of potential effects by three organisation types (airports, air navigation service providers (ANSPPs), aircraft operators) for each of the four climate impacts identified by respondents to the ICAO Climate Adaptation Synthesis stakeholder survey as of greatest concern (ICAO, 2020). Although the table presents a breakdown of potential effects by impact area, there will also be additional overarching effects such as an increase in the need for maintenance, repair and system overhaul. It is also important to consider effects holistically as an impact to one element of an organisation's assets or operations may have a knock-on effect on other elements. Additionally, although the tables focus on impacts of climate change, not all changes to climate will necessarily result in vulnerabilities, there may be positive opportunities as well. For example, in some areas, warmer winters may translate into less need for snow and ice removal for many airports.

### Small Island Developing States

Small Island Developing States (SIDS) are particularly vulnerable to climate change, and impacts of a changing climate can be magnified by other local issues. For example, SIDS often have constraints on personnel, funding, and limited land and water resources. For this reason, it is especially critical for SIDS to identify and prioritize vulnerabilities.

Potential effects from four main climate impacts to aviation risk categories<sup>1</sup>

<b>Airports</b>		
<b>Climate Impact</b>	<b>Risk Category</b>	<b>Potential Effect</b>
<b>Higher Average and Extreme Temperatures</b>	<b>Operations</b>	Runway length: <ul style="list-style-type: none"> <li>• Limits to operations due to reduced climb performance: higher temperatures reduce thrust and lift of aircraft during take-off, reducing take-off performance and requiring more fuel, or a reduction in overall weight.</li> <li>• Reduced ability of certain airports to take certain aircraft due to runway length limitations and reduced climb performance.</li> </ul>
		Greater noise impact and CO <sub>2</sub> emissions due to aircraft needing more thrust to take-off in less dense air.
		Increased risk of fire due to: <ul style="list-style-type: none"> <li>• Drought conditions</li> <li>• Higher extreme temperatures</li> <li>• Risk of ignition by the potentially higher amount of fuel vapour released by the increase thrust requirement at take-off</li> <li>• Increased prevalence of wildfires</li> </ul>
		An increase in bird strikes and other wildlife interactions, due to temperature-driven changes in species migration patterns and increased invasive species spread, both of which may lead to a change in wildlife hazard conditions.

<sup>1</sup> *Note on format of the tables:* Primary or key impacts are first level bullets and are likely to have the biggest effects. In some instances, secondary impacts are included as second level bullets. Although the effects may be less severe than for primary impacts, they nevertheless warrant attention.

<b>Airports</b>		
<b>Higher Average and Extreme Temperatures</b>	<b>Infrastructure</b>	Damage to airfield surface if temperatures exceed design standards.
		Stress on Heating, Ventilation and Air Conditioning (HVAC) Systems: <ul style="list-style-type: none"> <li>• Increased need for cooling capabilities                             <ul style="list-style-type: none"> <li>○ Duration of cooling required increases (more days per year and longer periods during the days)</li> <li>○ Higher cooling requirements to reach acceptable temperatures. (greater daytime temperatures)</li> </ul> </li> <li>• An increase in overall costs of HVAC operation.</li> <li>• Potential system failure – greater maintenance, a decrease in the lifespan of the HVAC systems.</li> </ul>
		Permafrost thaw, destabilizing and damaging ground infrastructure such as runways and access roads.
		Increase in maintenance and repair to: <ul style="list-style-type: none"> <li>• Runways</li> <li>• Taxi-ways</li> <li>• Other heat-vulnerable surfaces and infrastructure</li> </ul>
		Deterioration of electrical systems (including lighting and signage)
	Changes in ecosystem of water bodies receiving excess airport water could affect an airport's regulatory requirements for storm water discharge	
	<b>People</b>	Health and safety impacts to workers and passengers due to an increase in days with temperatures above 90°F/32°C. Humidity with high

<b>Airports</b>		
<b>Higher Average and Extreme Temperatures</b>	<b>People</b>	temperature can exacerbate the health of workers and passengers.
	<b>Business and economics</b>	Revenue losses and/or increased costs linked to: <ul style="list-style-type: none"> <li>• Airports' inability to accommodate certain aircraft</li> <li>• Changes in destination demand for air travel</li> <li>• Potential noise insulation or other mitigation measures</li> <li>• Additional firefighting services and wildlife management measures</li> <li>• Repairs (airfield surfaces, infrastructure, access roads, etc.)</li> <li>• Increased energy costs and requirements</li> <li>• Changes in waste management</li> <li>• Staff absenteeism due to injuries</li> </ul>
<b>Changing Precipitation</b>	<b>Operations</b>	Flooding and flood damage to runways and infrastructure
		Flight delays, cancellations and temporary airport closures
		Low visibility conditions
		Challenges to forecast conditions and precipitation type (e.g., rain, snow, freezing rain) resulting in less reliable forecasts to plan for operations
		<b>Snow</b> <ul style="list-style-type: none"> <li>• Snow events in new locations (lack of equipment/training)</li> <li>• Increased requirements for snow clearing and aircraft and runway de-icing equipment</li> </ul>

<b>Airports</b>		
<b>Changing Precipitation</b>	<b>Operations</b>	More challenging routine ground handling operations
		More maintenance, repair, and overhaul
		Warmer temperatures may result in an increase in ice events (as snow events are replaced by rain, freezing rain, and sleet), presenting more severe adverse impacts such as flight disruptions
		Increase in use of pavement de-icers for runways
		Warmer temperatures may result in an increase in aircraft icing events at low altitudes (early phase of take-off or final approach), with a strong impact on safety
		Increase in use of de-icing and anti-icing facilities for aircraft
	<b>Infrastructure</b>	Flooding due to insufficient capacity of storm drainage systems
		Failure of pollution control systems/contamination of groundwater due to inundation
		Disruption to ground transport links
		Damage to airport infrastructure from: <ul style="list-style-type: none"> <li>• Hail</li> <li>• Roof-overloading from heavy snowfall</li> <li>• Standing water from flooding</li> </ul>

## Airports

<p><b>Changing Precipitation</b></p>	<p><b>Infrastructure</b></p>	<p><b>Snow</b></p> <ul style="list-style-type: none"> <li>• Snow accumulation may interfere with regular maintenance/inspection schedules of oil/water separator, actuators and pumps, ventilation system, and valves</li> <li>• Heavy snowfall may interfere with regular maintenance/inspection schedules of inlets, outlets, ditches, diversion chambers, weirs, oil/water separator, all actuators and pumps, ventilation system, and valves                         <ul style="list-style-type: none"> <li>○ Personnel may have difficulty finding any valves/hatches covered in snow that have not been sufficiently marked</li> </ul> </li> <li>• Increased requirements for snow clearing and de-icing equipment</li> </ul> <p><b>Heavy Rain:</b></p> <ul style="list-style-type: none"> <li>• Maximum capacity of basins, inlets, outlets, ditches, diversion chambers, and weirs could be exceeded</li> <li>• The projected increase in storm intensity may result in rip-rap (e.g. rocks/rubble) being disturbed more often than usual creating more Foreign Object Debris (FOD)</li> </ul> <p><b>Winter rain and rain-on-snow:</b></p> <ul style="list-style-type: none"> <li>• Rain may melt snow creating additional runoff.</li> </ul> <p><b>Freezing rain:</b></p> <ul style="list-style-type: none"> <li>• The projected increase in freezing rain events may interfere with regular maintenance/inspection schedules of inlets, outlets, ditches, diversion chambers, weirs, actuators and pumps, ventilation system, and valves</li> </ul>
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<b>Airports</b>		
<b>Changing Precipitation</b>	<b>Infrastructure</b>	Reduced water availability due to drought
	<b>People</b>	Heavy rainfall, freezing rain, ice storm, hailstorm, snowstorm, blizzard, hurricane, tropical storm, or other precipitation events, may disrupt or prevent travel and restrict access to airports and air traffic facilities
		Passengers may be exposed to snow, rain, and / or freezing rain when embarking/disembarking aircraft which may result in safety hazards
<b>Business and economics</b>	Revenue losses and/or increased costs linked to: <ul style="list-style-type: none"> <li>• Flight delays, schedule changes, and cancellations</li> <li>• Interruption of operations</li> <li>• Infrastructure and airfield surfaces repairs and maintenance</li> <li>• Equipment acquisition</li> <li>• New training requirements</li> <li>• Safety incidents due to new equipment and procedures</li> <li>• Complex operations</li> <li>• Additional/new requirements for waste and water management.</li> <li>• Increased costs for de-icing fluids</li> </ul>	
<b>Increased Intensity of Storms</b>	<b>Operations</b>	Disruption to air traffic and airport operations; return-to-normal may take longer, more delays
		Impacts to runway use: airports runways can stay open during a storm event but operational use may be restricted so they can't be used by aircraft
		Delayed or cancelled flights due to threat of lightning strikes

<b>Airports</b>		
<b>Increased Intensity of Storms</b>	<b>Operations</b>	High winds contribute to blizzard and snowstorms which may limit visibility and have the potential to reduce or restrict airport operations
		Airport operations and equipment may be damaged in intense storms
		Impeded ground access, circulation, loading and unloading, parking, etc.
	<b>Infrastructure</b>	Airport infrastructure may be damaged or destroyed by intense storms, including storm surge, impacting: <ul style="list-style-type: none"> <li>• Availability of commercial power</li> <li>• Telecommunications services such as phone landlines, and cell phones</li> <li>• fuel supplies</li> <li>• car parking facilities</li> <li>• air conditioning and heating</li> <li>• ground transportation and airport access</li> <li>• drainage and run-off systems capability</li> <li>• deterioration and increased contamination of pavement surfaces</li> <li>• impeded ground access, circulation, loading and parking</li> <li>• increase in maintenance, repair, and overhaul</li> <li>• electrical system failure/shortage/spike</li> </ul>
		Facilities may be closed due to intense storms, such as tornado.
		Blowing snow/blizzard: <ul style="list-style-type: none"> <li>• A blizzard may interfere with regular maintenance/inspection schedules of oil/water separator, actuators and pumps, ventilation system, and valves</li> </ul>

<b>Airports</b>		
<b>Increased Intensity of Storms</b>	<b>People</b>	Passenger inconvenience from disrupted operations
	<b>Business and economics</b>	Revenue losses and/or increased costs linked to: <ul style="list-style-type: none"> <li>• Flight delays, schedule changes, cancellations</li> <li>• Operations interruptions</li> <li>• Infrastructure and equipment repairs, maintenance, etc.</li> <li>• Damage to infrastructure</li> <li>• New equipment acquisition, procedures and associated training</li> <li>• Emergency procedures and operations</li> <li>• Increase in use of snow removal equipment leading to an increase in overall costs</li> </ul>
<b>Sea Level Rise</b>	<b>Operations</b>	Temporary closures of coastal and river airports during recovery from a high tide or storm surge event.
		Permanent closures of coastal and river airports due to permanent inundation
		Inundation may limit or prohibit access to an airport
	<b>Airport Infrastructure</b>	Inundation of low-lying coastal infrastructure, including airport assets, the airfield, and ground transportation
		Drainage systems impacted as ground water tables are higher, increasing the risk of flooding
	<b>People</b>	Passenger inconvenience from flight delays or cancellations due to temporary inundation.

## Airports

<b>Sea Level Rise</b>	<b>Business and economics</b>	Revenue losses and/or increased costs linked to: <ul style="list-style-type: none"><li>• Flight delays, schedule changes, cancellations</li><li>• Interruptions of operations</li><li>• Infrastructure, airfield surfaces, and equipment repairs</li><li>• Emergency procedures and operations</li><li>• Negative public opinion</li></ul>
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<b>ANSPs</b>		
<b>Climate Impact</b>	<b>Risk Category</b>	<b>Potential Effect</b>
<b>Higher Average and Extreme Temperatures</b>	<b>Operations</b>	Stress to cooling capabilities Changes to safety criteria and procedures to account for reduced aircraft take-off performance
	<b>Infrastructure</b>	Damage to Navigational (NAV) equipment due to permafrost thaw, as well as higher than usual temperatures.
	<b>People</b>	Health impacts on employees
	<b>Business and economics</b>	Temperature-driven changes in demand for air travel
<b>Changing Precipitation</b>	<b>Operations</b>	Temporary reductions in capacity
		Delays and cancellations
		Low visibility conditions
		Challenging to forecast conditions and precipitation type (e.g., rain, snow, freezing rain): less reliable forecasts
		Re-routing of aircraft (e.g. due to heavy precipitation at an airport)
	<b>Infrastructure</b>	Flooding leading to damage to infrastructure
		Disruption to ground transport links
		Snow events in new locations
	<b>People</b>	Passenger inconvenience due to flight delays, cancellations, and reduced service capacity
	<b>Business and economics</b>	Financial impact of delays, cancellations and damage to infrastructure

<b>ANSPs</b>		
<b>Increased Intensity of Storms</b>	<b>Operations</b>	Disruption to air traffic operations, including delays and cancellations
		En-route and airport capacity limitations
		Loss of capacity at one airport can have knock-on impacts across the wider network
		Lightning strikes delaying or cancelling flights or restricting airport operations
	<b>Infrastructure</b>	Lightning strikes may incapacitate towers/radar
		Facilities may be closed due to intense storms, such as tornado
		Lightning strikes damaging aircraft, airport, or air traffic infrastructure
		Damage to NAV aids, particularly in remote locations.
	<b>People</b>	Passenger inconvenience due to flight delays, cancellations, and reduced service capacity
		Ability of employees to get to work or facilities. Danger to front line workers that maintain facilities
<b>Business and economics</b>	Financial impact of delays, cancellations and damage to infrastructure	
<b>Sea Level Rise</b>	<b>Operations</b>	Temporary closure of airport impacting operations
	<b>Infrastructure</b>	Inundation of low-lying coastal infrastructure, including navigation and communication equipment, the airfield, and ground transportation

## Aircraft Operators

Climate Impact	Risk Category	Potential Effect
Higher Average and Extreme Temperatures	Operations	<p>Aircraft performance:</p> <ul style="list-style-type: none"> <li>• Maximum take-off weight may be restricted (reduced “lift” of aircraft during take-off, requiring more fuel, or reduction in overall weight)</li> <li>• Lower air density may require aircraft to operate at higher take-off thrust, which increases maintenance costs and fuel consumption</li> </ul>
		Greater noise impact and CO <sub>2</sub> emissions due to more thrust for aircraft to take-off in less dense air
		Reduced visibility (visual and signal line of sight issues) e.g. from heat haze
		All aircraft have a range of temperature for which they are certified. This temperature range varies by aircraft, and by variant within an air frame type. An aircraft may be grounded, and prevented from operating if outside temperatures are not within the range for the aircraft to operate.
		Additional cooling requirements for aircraft on the ground, increasing energy consumption from Auxiliary Power Unit (APU), Ground Power Unit (GPU) or pre-conditioned air
		Disruption to fuel supply chain due to wildfires may impact availability of fuel, and other supplies, at airports

<b>Aircraft Operators</b>		
<b>Higher Average and Extreme Temperatures</b>	<b>Infrastructure</b>	Increase in maintenance and repair
		Heat-related weathering of fleet, including tires and air conditioning capabilities
	<b>People</b>	Health impacts on employees flight crew, airline staff and passengers (e.g. increase in the possibility of heat stroke)
		Passenger and personnel discomfort due to strains on air conditioning systems
		More hazardous aircraft turnaround operations for personnel
	<b>Business and economics</b>	Temperature-driven changes in demand for air travel due to long-term shifts in travel demand to specific destinations (e.g. capacity stress due to optimising fleet to meet new demand requirements and potential recruitment or redeployment of staff).
Reduced payload capacity resulting in reduced revenue. Increased maintenance resulting in higher operational costs.		
<b>Changing Precipitation</b>	<b>Operations</b>	Reductions in capacity
		Delays and cancellations
		Temporary airport closures
		Increased requirements for snow clearing and de-icing equipment
		Re-routing of aircraft



<b>Aircraft Operators</b>		
<b>Changing Precipitation</b>	<b>Operations</b>	Flooded airport surfaces, impeding aircraft movements and ground servicing operations
		Increased risk of runway excursion upon landing or during take-off due to degraded or irregular surface friction coefficient
		Drought-induced water shortages requiring tankering of potable water, increasing fuel consumption and emissions
		Increased runway de-icing causes higher fan blade erosion, which reduces fuel efficiency and increases maintenance and operational costs
		Challenges to forecast conditions and precipitation type (e.g., rain, snow, freezing rain), leading to less reliability
	<b>Infrastructure</b>	Snow, hail, and/or freezing rain events in new locations: <ul style="list-style-type: none"> <li>• Delays and cancelations of flights</li> <li>• Restrictions in airport operations</li> <li>• Safety risks due to freezing rain, rain and/or snow</li> </ul>
		Disruption to ground transport links
		More maintenance, repair, and overhaul
	<b>People</b>	High humidity combined with higher temperatures results in additional health and safety risks
	<b>Business and economics</b>	Increased operational costs

<b>Aircraft Operators</b>		
<b>Changing Precipitation</b>	<b>Business and economics</b>	Uncertainty in new markets or how markets will change e.g. due to changes in frequency and intensity of rain or prevalence of snow.
<b>Increased Intensity of Storms</b>	<b>Operations</b>	Lightning strikes
		Delays and cancelations
		En-route capacity limitations and deviations
		Airport capacity limitations, including restrictions in services due to ground-level impacts (e.g., flooding and storm water inundation)
		Increased damage from foreign objects
		Increased fuel burn and emissions
		Blowing sand and dust in desert environments, resulting in reduced visibility, flow restrictions, and health impacts
		Wind shear and turbulence
		Deeper storms resulting in changing icing patterns
		Disruption to fuel supply chain may impact availability of fuel at airports
	<b>Infrastructure</b>	Increase damage to planes, Ground Service Equipment (GSE), and other assets.
	<b>People</b>	Passenger inconvenience
		Staff and passenger health and safety risk

## Aircraft Operators

<b>Increased Intensity of Storms</b>	<b>Business and economics</b>	Lost revenues, increased operating costs
<b>Sea Level Rise</b>	<b>Operations</b>	Re-routing. Closure of operations at certain airports / closure of routes where alternative airports are not available if sea level rise closes airport.
	<b>Infrastructure</b>	Inundation of low-lying coastal infrastructure: <ul style="list-style-type: none"> <li>• Navigation and communication equipment</li> <li>• Airport infrastructure</li> <li>• The airfield</li> <li>• Ground transportation</li> </ul>
		Salt damage to aircraft
	<b>People</b>	Disruption for passengers due to delayed, cancelled or rerouted flights.
		Hazards for ground staff due to inundation.
	<b>Business and economics</b>	Lost revenues, increased operating costs