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04 / EUROPEAN AVIATION IN 2040 - CHALLENGES OF GROWTH - ADAPTING AVIATION TO A CHANGING CLIMATE	

SUMMARY

This report is part of the fifth Challenges of Growth study, which aims to deliver the best-achievable information to support long-term planning decisions for aviation in Europe. It is the second annex to the summary report "European Aviation in 2040" (Ref. 1) and considers the challenge of adapting to climate change.

The climate is changing and this will impact European aviation. Over the medium and long term there will be changes to temperatures, to rain, snow, wind and storm patterns, and in the sea-level. These will impact aviation operations, infrastructure and underlying demand.

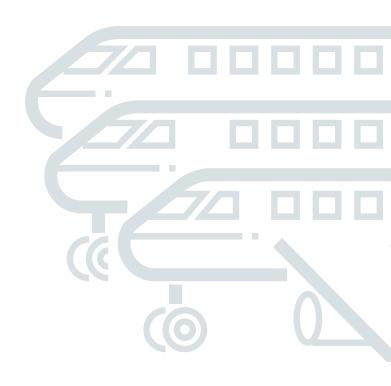
A re-run of the 2013 climate adaptation stakeholder survey suggests that awareness of such potential impacts of climate change, and the need to adapt and build resilience, is increasing. More than 90 responses to the survey were received from air navigation service providers, airport operators, airlines, civil aviation authorities and manufacturers from across Europe covering all of the main European climate zones. A majority of respondents expect climate change to affect their business by 2050. Around a quarter of overall respondents are already experiencing some impacts of climate change.

Stakeholders expect higher temperatures, increased precipitation, extreme weather and changing wind conditions to be the main challenges they will need to address. They expect these to generate operational impacts and changes to the costs of operating their business. A small number view climate change as a positive opportunity.

Eighty-six percent of respondents expect adaptation to the impacts of climate change to be necessary and a growing number of organisations are starting to carry out risk assessments and develop adaptation strategies: 53% have currently begun adaptation and resilience planning.

Impacts and adaptation measures required will vary according to climate zone, geographical location and type of operation, and individual organisations will take their own adaptation planning decisions. However, a risk assessment can be a solid basis for assessing what actions are required.

Stakeholders consider that both the European aviation sector as a whole, and European ATM in particular, are taking measures to adapt to climate change, but that more still needs to be done. The extent to which adaptation measures are required is each organisation's decision but, due to the interconnectedness of the European and global aviation systems, an integrated and collaborative approach to building resilience is required; we need to assess whether sufficient measures are being implemented quickly enough, or whether we need to accelerate action





INTRODUCTION

The *Challenges of Growth* studies aim to deliver the best-achievable information to support long-term planning for aviation in Europe. EUROCONTROL has completed four *Challenges* studies, in 2001, 2004, 2008 and 2013 (Ref. 2, 3, 4, 5). The fifth study, Challenges of Growth 2018 (CG18) tackles the following question:

What are the challenges of growth for commercial aviation in Europe between now and 2040?

A series of annex reports supports the summary report "European Aviation in 2040" (CG18, Ref. 1):

- **Annex 1**, reports in detail the forecast of flights to 2040 and the effects of capacity constraints at airports (Ref. 6)
- Annex 2, this report, gives an up-dated assessment of the readiness of the aviation industry to adapt to the effects of climate change.
- Annex 3 looks at ways to mitigate the lack of capacity, starting with building more airport capacity, but also how to use differently what capacity there is (Ref. 7).
- **Annex 4** reports on the impact of this lack of capacity in terms of congestion and delays (Ref. 8).

REPORT STRUCTURE

This report builds on the *Challenges of Growth 2013* Climate Change Risk and Resilience report (Ref. 11) to further consider the challenge of adapting our sector to a changing climate. It also gives an updated assessment of the readiness of the aviation industry to adapt to the effects of climate change.

The report is structured as follows:

- In the first section we look at how awareness of the potential impacts of climate change and the need to adapt and build resilience is growing.
- The next section looks at the latest IPCC climate change projections.
- We then introduce the Challenges of Growth 2018 Climate Adaptation stakeholder survey and give some initial results.
- The next sections consider the potential physical impacts of climate change and take a high-level look at some potential adaptation measures, as well as how impacts may vary for different types of organisations.
- In the final section we present the results of the 2018 Climate Adaptation Stakeholder Survey.



THE ADAPTATION CHALLENGE

Awareness of the potential impacts of climate change, and the need to adapt and build resilience, is increasing. More organisations are starting to carry out risk assessments and develop adaptation strategies.

The move to adapt and build resilience to the potential impacts of climate change is gaining momentum. The science has been certain as to the main impacts to expect for some time. The political will is now increasing and more challenging targets are being set. At the same time, recent high-profile extreme weather events have given us a taste of what we will increasingly have to deal with. The incentives to act are many, but centre on reducing vulnerabilities, damage and costs, and are increasingly driven by policy and legislation. For the aviation sector, two key objectives of adaptation are business continuity and protection of critical infrastructure. The sector is used to operating in challenging weather conditions, but climate change will make disruptive weather events more frequent, more intense, and potentially occurring in unexpected locations or with unexpected timing. At the same time, the underlying climate will change, potentially leading to more challenging daily weather conditions, and there may be longer periods of extreme conditions such as heatwaves. Daily operations, infrastructure and underlying demand will all be affected.

The Operational Incentive:

When disruption leads to the cancellation, delay or re-routing of a flight there is a financial penalty, an impact on subsequent operations, and reputational risk. Moreover, the industry has a strong motivation to ensure its excellent safety record in more challenging conditions. Therefore, measures are needed to maintain smooth operations in the face of disruption and to ensure that aircraft, infrastructure and personnel are prepared to operate in changing climatic conditions.

The Business Incentive:

Disruption and damage cost money. Therefore, organisations need to take measures to protect their infrastructure, their operations, and their staff and customers against more challenging conditions. Climate change may also affect demand patterns, with traffic flows changing geographically or seasonally, which would impact business planning and revenue streams. A robust risk assessment is recommended to avoid the costs of over- or under-adaptation.

The Regulatory Incentive:

Adaptation is now enshrined in the United Nations Framework Convention on Climate Change (UNFCCC) landmark 2015 Paris Agreement. Article 7 of the agreement establishes "the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change" (Ref. 10, p.9). In addition, the United Nations International Civil Aviation Organisation (ICAO) now has a task to look at the potential impacts of climate change for the global aviation sector.

CLIMATE CHANGE PROJECTIONS

The Challenges of Growth 2008 Environment Report (Ref. 9) identified the environmental factors which could constrain the European aviation network for the following 20 years. The study highlighted for the first time that climate change could impact the European aviation sector, potentially affecting infrastructure, operations and demand to travel. The Challenges of Growth 2013 Climate Change Risk and Resilience report (Ref. 11) went on to explore in more detail what the potential risks might be and to identify possible adaptation measures. It also presented the results of a survey of European aviation stakeholders, which gathered their views as to whether they considered the potential impacts of climate change to be of concern and whether or not action to adapt to those impacts was needed. It demonstrated that, although many European aviation stakeholders were starting to consider climate change impacts as a risk, few had started to take action to adapt, with several respondents indicating that they were not aware of the issue or did not have enough information or guidance to take action.

Since 2013, climate change and the need for adaptation have gained much more prominence through the publication of new scientific information, the development of national and global adaptation policies, and a number of highprofile disruptive weather events which give us an indication what we might have to face as the climate changes. Given the increasing recognition that, despite increased mitigation measures, some degree of adaptation will be required, for Challenges of Growth 2018 we follow up on the 2013 report by identifying to what extent our industry now views the impacts of climate change as a risk and which actions it is taking as a result. The report also provides an update on new scientific developments in this field since 2013.

Projections of climate change impacts are not static and the climate can change in a different way or at a different pace to that forecast previously. New and improved data sources also provide opportunities to refine the calibration of models. Therefore, it is important to re-run forecasts on a regular basis, and to update plans for climate change adaptation accordingly. Since Challenges of Growth 2013, the two main scientific documents that were referenced, the IPCC Assessment Reports and the European Environment Agency (EEA) Climate Change Impacts and Vulnerabilities report, have both been updated (Ref. 12; Ref. 13). Over this period the science has remained reasonably stable but, notably, the IPCC has changed its forecasting method and introduced a new set of scenarios called the Representative Concentration Pathways (RCP). The RCPs are "Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover" (Ref. 12, p.126). Table 1 (on page 19) gives an overview of the scenarios. This report updates the 2013 report with the IPCC's updated forecasts.

For scenario RCP6.0 between 2046 and 2065 the projected temperature increase is slightly lower than the projected increase for the scenario RCP4.5 due to different emissions trajectories. Under scenario RCP4.5 emissions peak around 2040 then decline, whereas under RCP6.0 they do not peak until 2060 (Ref. 14; Ref. 15; Ref. 16). There is currently no consensus as to which IPCC scenario we are heading towards. The scenarios are based on different assumptions as to population and economic growth, and energy consumption. At present, all of the scenarios are still feasible. However, according to the Climate Action Tracker¹ (Ref. 17), with current policies, warming is projected to reach 3.4°C (+2.5 to +4.7 °C) by 2100, corresponding to the IPCC high emissions scenario RCP8.5. According to current Paris Agreement Nationally Determined Contributions (NDCs), i.e. the mitigation actions which States have committed to make, warming will reach +3.2°C (+2.6 to +4.0 °C), also corresponding to a high emissions scenario (Ref. 17).

The Climate Action Tracker is an independent scientific analysis produced by three research organisations, Climate Analytics, NewClimate Institute and Ecofys, which track the progress towards the goal of keeping warming well below 2°C.

Scenario	Level	Global mean surface temperature change (°C) 2046-2065	Global mean surface temperature change (°C) 2081-2011
RCP2.6	Low greenhouse gas emissions	1.0 (0.4 to 1.6)	1.0 (0.3 to 1.7)
RCP4.5	Stabilisation without overshoot- intermediate emissions	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP6.0	Stabilisation without overshoot-intermediate emissions	1.3 (0.8 to 1.8)	2.2 (1.4 to 3.1)
RCP8.5	High greenhouse gas emissions	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)

Table 1 / IPCC RCP Scenarios and their projected temperature outcomes (Source: IPCC, 2013).

Colder than the Pole?

Climate change can be unpredictable! Although we think we know what to expect in general, there may still be surprises ahead, such as the unseasonably cold Spring of 2018! Heavy winter storms hit much of Europe bringing late snow and freezing temperatures with, at some points, parts of Europe colder than the North Pole and snow cover extending much further South than is usual. This initially seems to be the opposite of what we have been told to expect from climate change. But some scientists hypothesise that this unusual cold weather may have been influenced by an unseasonably warm Arctic, and a break in the polar vortex expelling cold fronts in Europe's direction (Ref. 18; Ref. 19). Of course, one event does not prove a theory, and more research is required. But it is likely that as well as the more generally-expected higher average and extreme temperatures, more disruptive and less predictable weather of all sorts could be ahead.

CHALLENGES OF GROWTH 2018 CLIMATE ADAPTION SURVEY

Update of the 2013 survey to find out what stakeholders now think of this issue and whether they are taking action. 93 responses received from air navigation service providers, airport operators, airlines, civil aviation authorities and manufacturers across the main European climate zones.

The 2013 Challenges of Growth study reported the results of a consultation of European aviation stakeholders which gathered views as to whether they considered the potential impacts of climate change to be of concern and whether or not action to adapt to those impacts was needed. A key part of that consultation was a stakeholder survey. The results can be found in the Climate Change Risk and Resilience report (Ref. 11).

For Challenges of Growth 2018, a follow-up survey was launched to determine to what extent the European aviation sector now considers the potential impacts of climate change to be of concern and whether or not organisations within the sector have been taking action to adapt to those impacts. The intention was also to compare results with the corresponding survey carried out in 2012-13 to determine whether and to what extent our industry has changed its view of these risks.

The survey was launched on January 22nd and ran until 28th February 2018. It was sent to approximately 200 organisations and 93 valid results were received. This is more than double the 35 responses received for the 2013 survey, which we believe is for a combination of two reasons: greater general awareness of this issue within the sector, and the wider publicity given to the survey via social media.

Responses came from across Europe and, critically for this report, covered all of the main climate zones and were from a range of aviation stakeholders including air navigation service providers, airport operators, airlines, civil aviation authorities and manufacturers. Compared to 2013, responses were received from a wider range of stakeholders, which may contribute to some of the differences with 2013.

When looking in detail at the statistics of the responses, we should be aware that there may be some degree of self-selection bias with organisations that have an interest in or are already engaged with this issue being more likely to respond. We deliberately used the same questions as in 2013, with some minor edits for clarity, but, due to the relatively low numbers of responses in 2013, we have no expectation that differences in the replies between 2013 and 2018 will be statistically significant. Where we talk about changes or consistency between 2013 and 2018 below, these comments should be taken as broadly reflecting the response, backed up by verbal feedback, and communication with stakeholders across the industry over the last five years.

THE IMPACTS OF CLIMATE CHANGE FOR EUROPEAN AVIATION

With a broader-based survey, a majority of respondents expect climate change to affect their business by 2050. Around a quarter of overall respondents are already experiencing some impacts of climate change

The number of European aviation organisations that expect climate change to impact their business is growing. 53 respondents (57%) to the Challenges of Growth 2018 survey expect the impacts of climate change to affect their business between now and 2050 (N = 93, Figure 1). This is a small increase in percentage terms compared to the 52% of organisations in 2013 that expected climate change to impact them. However, in actual terms it may represent a bigger increase as there were only 33 valid responses to this question in 2013 compared to 93 in 2018. Nine of the 2018 respondents (10%) do not expect climate change to affect their organisation, whilst 31 (33%) do not have an official position. This compares to 3% (no effect expected) and 45% (no position) in 2013. Therefore, although the number of respondents that expect to be impacted has increased, so has the number of respondents that do not expect to be affected, with the biggest change in the number of organisations that do not have an official position. This could imply that awareness of this risk is growing and a greater number of organisations are engaging with the issue, although this cannot be said with certainty. The increase in organisations that do not expect to be affected may be for a number of potential reasons. It may be due to a change in the types of organisations that responded (although it should be noted that not all respondents identified the category of their organisation), it could be because of the organisation's geographical location, or it may be that respondents have now carried out a risk assessment and concluded that they do not expect to experience significant impacts.

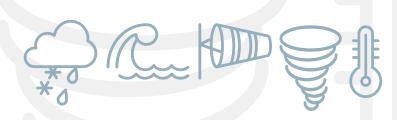
EXPECT CLIMATE CHANGE IMPACTS 57%

NO OFFICIAL POSITION 33%

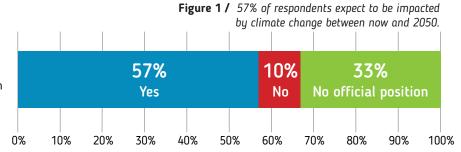
EXPERIENCING THE IMPACTS 48%

EXPECT TO EXPERIENCE BY 2030 26%

NEED TO ADAPT



% of organisations that expect the impacts of climate change to affect their business between now and 2050



Organisations that said that they do not expect to be affected stated that this was because they were already well-prepared, because they did not expect to experience climate change until after 2050, or predominantly (5 out of 8 respondents that answered the question) that they do not expect to experience significant impacts. Respondents that gave this answer were from a range of organisations and locations with no particular stakeholder group assessing that it would not be affected, and no clear geographical patterns.

Respondents whose organisations do not have an official position were asked a follow-up question as to whether they were taking any measures to establish whether climate change might affect them. Of the 31 respondents that answered the question, 18 are taking measures, for example to identify potential risks and develop plans, eight answered that they do not know whether measures are being taken, and seven that no measures are being taken, although in several cases this was because the task was considered to be the responsibility of another entity.

TIMESCALES

Earlier in the report we discussed recent unusual weather patterns and their physical causes (see text box "Colder than the Pole?"), but cautioned that individual extreme or unusual weather events cannot yet be linked directly or with certainty to a changing climate. Climate scientists will only be confident of more permanent shifts, rather than temporary deviations, after an accumulation of data and longer-term analysis. Nevertheless, exceptional weather locally and a media narrative of extreme weather worldwide is convincing many more people to take climate change seriously and engage in mitigation and adaptation action. And talking to our operational stakeholders, many already report seeing changes in regular weather patterns, such as more severe disruptive weather, that impact their operations.

Almost a guarter of all respondents, i.e. almost half of the 42 respondents that answered the particular survey question on timescales (48%), are already experiencing the impacts of climate change, 11 respondents (26%) expect to experience it by 2030 and 7 respondents (17%) by 2050 (N=42, Figure 2). This compares to 37% in 2013 that stated that they were already experiencing impacts, 13% expecting impacts by 2030 and 13% by 2050. In 2013, 37% of organisations stated that they expected to experience the impacts of climate change by 2020 compared with just 9% in 2018. This suggests that some of the organisations that were expecting to experience impacts may indeed have begun to do so, but also, given that 2020 is just two years away respondents that are not yet affected may have selected 2030 as their answer. As with 2013, cross-analysis by type of organisation demonstrated no clear patterns as to whether any particular part of the sector could be considered more vulnerable. Also, as with 2013, it is likely that there may have been some degree of self-selection with organisations that are already experiencing impacts more likely to respond to this question.

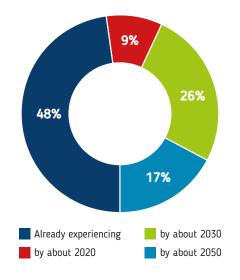


Figure 2 / 48% of respondents to this question are already experiencing some impacts of climate change.

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THE PHYSICAL IMPACTS OF CLIMATE CHANGE

Stakeholders expect higher temperatures, increased precipitation, extreme weather and changing wind conditions to be the main impacts to address. They expect this to affect operations and increase operating costs. A few respondents view climate change as a positive opportunity.

The key potential risks of climate change for the European aviation sector were identified in the Challenges of Growth 2013 "Climate Change Risk and Resilience" report, namely:

- Temperature increase
- Changes to precipitation (rain and snow)
- Changes to storm patterns²
- Changes in wind patterns
- Sea-level rise and storm surges

These key risks remain the same and are categorised in a broadly similar way across the literature. However, knowledge has been updated in a number of areas. The subsequent sections will explore these updates.

The main physical climate change impacts which respondents expect to affect their organisations are an increase in extreme weather, higher temperatures, changes in wind conditions and increased precipitation (Figure 3). This is consistent

with the 2013 report (Ref. 11) where these impacts were also highlighted and changes in wind conditions were consistently identified as a potential issue in the "other" category. It is also consistent with the main climate change impacts identified in the literature. Sea-level rise is likely to have been considered a key impact by fewer respondents as it is a more localised issue, although one of the "other" answers identified rising ground water levels as a potential risk. Potential changes in traffic demand were also highlighted by a number of respondents as another possible effect, as was an increase in en-route turbulence. These may be impacts which stakeholders are already seeing or expect to experience in the future, and their concurrence with the science suggests that we now have a good overview of the challenges that our sector may have to deal with. As we mentioned above, a substantial number of respondents stated that they are already having to deal with the impacts of climate change. For them, these impacts will be actual, rather than potential.

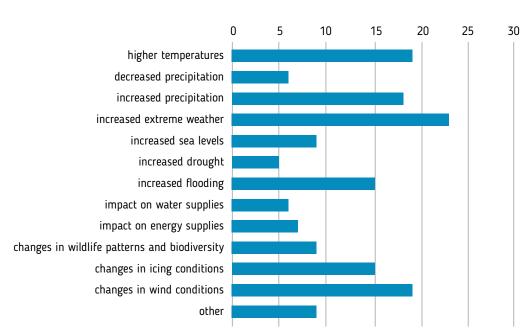


Figure 3 / The main climate change impacts which European aviation stakeholders expect to be affected by are increased extreme weather, higher temperatures and changes in wind conditions (some respondents gave more than one answer).

2/
In the 2013 report this category was referred to as "Increased convective weather". For 2018, we have re-categorised it as "Changes to Storm Patterns" to better capture the different types of and changes to storms which may affect

The main effects which stakeholders expect from the physical impacts of climate change are operational impacts and changes to the costs of operating their business. Loss of or damage to infrastructure and safety were also highlighted as key risks (Figure 4). These are broadly the same issues which stakeholders identified in 2013. However, in 2013 no respondents identified climate change as a

positive opportunity for their organisation, whereas in 2018 six out of 41 respondents that answered this question considered climate change may be an opportunity. Although the reasons for this were not specified, possible reasons could include a decrease in severe winter weather and de-icing demand or an increase in business opportunities such as tourism demand.

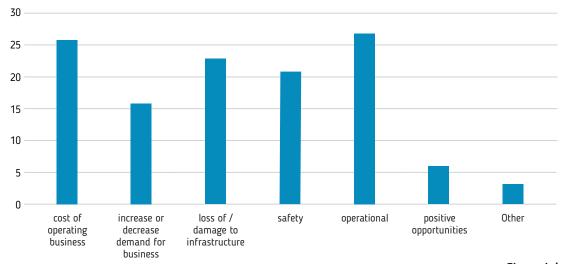


Figure 4 /
The main effects which respondents expect climate change to cause for their organisation are operational and financial (some respondents gave more than one answer).

THE CHALLENGES OF CHANGING TEMPERATURES

Warming will not be even. Some parts of Europe could experience 4-5°C of temperature increase under a high emissions scenario. In these circumstances aircraft performance would be impacted, there may be heat damage to infrastructure and possible geographical and seasonal changes to demand.

THE CLIMATE IMPACT	THE AVIATION IMPACT
 European land areas continue to warm faster than the projected global average increase Projections vary according to IPCC scenario: RCP4.5 = 1 to 4.5°C³ increase and RCP8.5 = 2.5 to 5.5°C Warming will not be seasonally or geographically even. Strongest warming will be in north-eastern Europe and Scandinavia in winter and southern Europe in summer Changes to permafrost 	 Aircraft performance changes Runway length issues Yield and range issues Demand redistribution (geographical) Demand redistribution (seasonal) Increased cooling and heating requirements Heat damage to airport surfaces (runways and taxiways) Structural issues due to changes to permafrost

2071-2100 compared with 1971-2000.

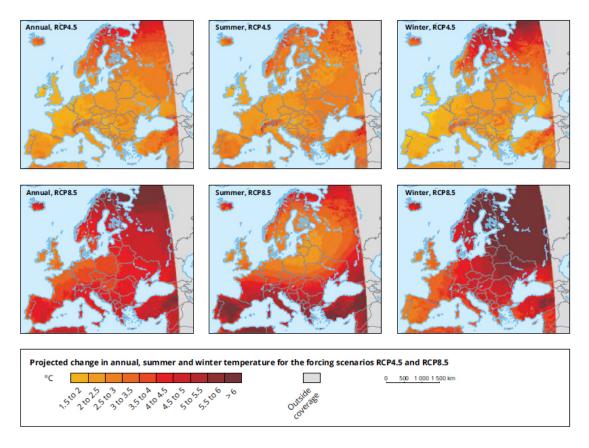


Figure 5 /
Projected changes in annual, summer and winter near-surface air temperature (°C) for 2071-2100
compared with a 1971-2000 baseline (Source: EURO-CORDEX (Jacob et al, 2014) in EEA 2017)

Figure 5 shows geographical differences in projected warming, with southern Europe warming more strongly in summer and north-eastern Europe and Scandinavia in winter. Even under the IPCC medium emissions scenario (RCP4.5) most of Europe can expect a minimum of 2°C warming by the end of the century.

ACTIONS TO ADAPT

Aircraft operators need to be prepared for changes in aircraft performance due to both higher average and extreme temperatures. Consideration may need to be given to rescheduling heavier aircraft departures to cooler times of the day (as already happens in some locations) or even reducing payload. Airport cooling requirements may increase to limit the effects of high temperatures on passengers and staff. Development or renovation of infrastructure should consider measures such

as materials and design to facilitate natural cooling. Heating requirements may also increase if more extreme winter weather can be expected. Local climate forecasts can be used to assess whether airport surface material specifications will be sufficient for future average and extreme temperatures. Both forecast temperature changes and potential geographical changes in traffic demand should be considered when planning infrastructure projects. Seasonal changes in demand which shift tourism demand to the shoulder months may reduce controller workload and pressure on airport capacity during the peak summer months.

STAKEHOLDERS' VIEWS

Stakeholders identified changing temperatures as one of the main climate impacts they expect to have to deal with. Specific impacts which respondents identified include higher cooling demand due to higher average and extreme temperature, long-term droughts, and wild fires.

- "... higher cooling demand [due to] higher average and extreme temperatures" CAA/Regulator
- "... long term droughts" CAA/Regulator
- "... Extremely high temperatures" CAA/Regulator
- "... Change in permafrost in Greenland" CAA/Regulator

High heat, low lift

Exceptional temperatures in the Southern United States in summer 2017 caused the cancellation of flights for some smaller aircraft that were not certified to operate at the temperatures reached. In fact this situation is not unique, with several airports around the globe already scheduling heavier departures for cooler parts of the day to accommodate higher temperatures, higher altitudes or shorter runways. This is because as air temperature increases, air density declines and lift is reduced for any given speed so more thrust and runway length are required to get airborne.

However, as climate change increases both average and extreme temperatures, such situations may become more common. A recent study identifies a number of airports worldwide where weight restrictions to aircraft may be required due to an increase in high-heat days. In particular, airlines using airports with short runways or at high altitudes may need to adjust schedules or lower payloads to deal with this, with a resulting impact on their operations and revenues as well as those of the airports (Ref. 24).

THE CHALLENGES OF CHANGING PRECIPITATION (RAIN AND SNOW)

Heavy precipitation will increase in most of Europe. Snow will generally decrease, although with a potential increase in heavy snowfall events. Heavy precipitation and snow can disrupt operations and reduce airport throughput.

THE CLIMATE IMPACT

- Changes to precipitation will vary seasonally and geographically: an increase in annual precipitation in the North and a decrease in the South of Europe
- An increase in heavier precipitation events, particularly in North Eastern Europe, and an increase in longer dry periods can be expected
- In general, snow cover will continue to decrease and snow seasons become shorter, although there may also be an increase in heavy snowfall events due to the ongoing decrease in Arctic sea ice

THE AVIATION IMPACT

- Disruption to operations e.g. delays or cancellations
- Airfield flooding and drainage system overload
- Reduced airport throughput
- Change in snow clearance and de-icing requirements
- Inundation of underground infrastructure
- Impact on ground transport access
- Freezing rain impacting operations

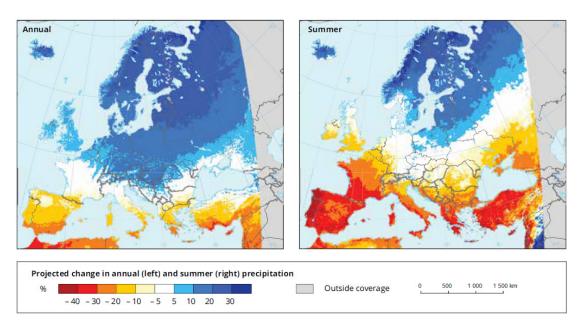


Figure 6 / Projected changes in annual (left) and summer (right) precipitation (%) in the period 2071–2100 compared with a baseline period of 1971–2000 period for the IPCC scenario RCP8.5. (Source: EURO-CORDEX (Jacob et al, 2014) in EEA 2017)

Figure 6 shows a significant increase in annual precipitation in much of northern and central Europe and a decrease in southern Europe by the later part of the century according to the IPCC high emissions scenario (RCP8.5). In summer, more of central Europe and some parts of northern Europe

will also experience a decrease, although much of northern Europe will see an increase. For the IPCC medium emissions scenario (RCP4.5, not pictured), the geographical and seasonal pattern of change is very similar to the high emissions scenario although the extent of the change will be smaller (Ref. 13).

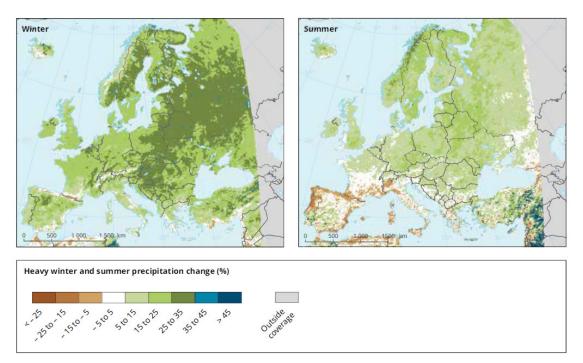


Figure 7 / Projected changes in heavy precipitation in winter (left) and summer (right) in 2071-2100 for the IPCC high-emissions scenario (RCP 8.5) compared to a baseline of 1971-2000. (Source: EURO-CORDEX (Jacob et al, 2014) in EEA 2017)

Heavy precipitation can affect airport operations. Figure 7 shows that most, although not all, areas will see an increase in heavy winter precipitation, which can disrupt operations by the latter half of the century. In the summer, northern and eastern Europe will see an increase in precipitation, whilst the South will see a decrease, although this is for the highest emissions IPCC scenario (RCP8.5). For the intermediate emissions scenario (RCP4.5) similar seasonal patterns are expected although the magnitude of change will be smaller. Geographically, with the exception of some areas of southern Europe, no decrease in heavy precipitation is forecast under this scenario (Ref. 13).

ACTIONS TO ADAPT

Local climate forecasts can be used to assess whether drainage capacity is adequate over the full expected lifetime of the installation. The introduction of operational measures, such as Airport-CDM4, can increase robustness and flexibility. Improved use of meteorology (MET) forecasting can facilitate making operational decisions, as can information sharing with SWIM5. Training is also key to ensure that staff know how to interpret MET data, as well as how to react during disruptions to operations. Snowfall has the biggest impact in areas where it is not expected, suggesting that even aerodromes in areas that do not regularly experience snowfall should have a plan in place for snow and ice removal, and a contingency plan for access to equipment. On a positive note, in some areas there may be a decrease in de-icing requirements and snowfall events.

To prepare for a decrease in rainfall and a potential increase in drought, organisations can consider measures to reduce water consumption. This is a win-win measure in that it can also lead to reductions in costs.

STAKEHOLDERS'VIEWS

An increase in precipitation and risk of flooding were two of the main risks identified by survey respondents, although fewer expect to be affected by a decrease in precipitation. Specific impacts identified included flooding, including flash floods, and long term drought. More positively a potential reduction in the need for de-icing requirements was identified. Stakeholder organisations also identified the need to engage with their staff and to provide them with training.

- "... Reduction of ... de-icing fluid consumption"
- "... Floods and flash floods"
- "... Long term droughts"

|||||||

"... Staff engagement"

Airport Collaborative Decision Making (Airport-CDM) is a system where airport partners work together and share data and information to make decisions which optimise airport operations.

System Wide Information Sharing (SWIM) is a process for information sharing.

THE CHALLENGES OF CHANGING STORM PATTERNS

Uncertainties remain as to how climate change will impact storminess, but larger and more damaging storms are likely to increase in number. Storms can disrupt operations and impact capacity. Translating MET data to inform operational decisions is key.

THE CLIMATE IMPACT THE AVIATION IMPACT Uncertainties as to changes in frequencies, Disruption to operations: delays, re-routings, intensity and location of storms: studies route extensions and increased fuel burn showing considerable variability Potential en-route capacity loss and Studies typically agree on an increase in congestion the number of the strongest and most Less predictability for 4-D trajectories damaging storms across all regions Larger and more intense convective systems Potential increase in severe autumn and could affect multiple hub airports winter storms for the North Atlantic and Damage to infrastructure northern, north-western and central Europe Increase in lightning strikes Possible increase in cyclones in central Europe due to an eastward extension of the North Atlantic storm track ■ In the Mediterranean, tropical-like cyclones may increase in intensity but decrease in frequency

Table 4 / The potential impacts of increased convective weather (Refs. 11, 13, 22, 27, 28)

There are many uncertainties as to how storm patterns will change: study results show considerable variability and there are likely to be regional and seasonal differences. However, studies generally concur that stronger, and thus more damaging, storms will be more frequent across Europe.

ACTIONS TO ADAPT

Good meteorology (MET) information is key to dealing with disruptive weather such as storms. MET capabilities are improving, but it is important that operational staff have the training to translate MET information into operational decisions such as pre-emptively cancelling flights, reducing capacity or diverting aircraft. If convective systems become larger and more intense, potentially affecting multiple airports, then extra fuel may be required to reach alternative diversionary airports.

On-board technology for detection of weather systems and information sharing, e.g. through SWIM, could also increase resilience.

Although lightning strikes may increase as a result of atmospheric warming, aircraft are designed to be protected from serious impact. However, more frequent lightning strikes could cause an increase in damage to aircraft and thus in maintenance costs (Ref. 29; Ref. 30).

STAKEHOLDERS' VIEWS

Although the survey did not ask about storms explicitly, the impact which respondents expect to be most affected by is an increase in extreme weather, which of course incudes intense and damaging storms. Stakeholders highlighted that extreme weather events were likely to become more frequent and more intense, leading to impacts for both passengers and operations, and damage to infrastructure.

- "... Damage to infrastructure affected by increased intensity of storms"

 CAA/Regulator
- "... More occurrences of extreme weather ... leading to air transport delays and passenger inconvenience"

 CAA/Regulator
- "... Extreme meteorological events" CAA/Regulator

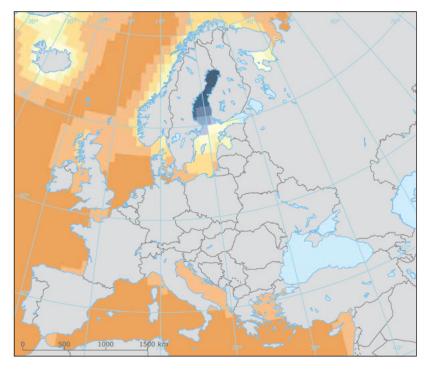
THE CHALLENGES OF SEA-LEVEL RISE AND STORM SURGES

Sea-level rise will occur in the longer term. There may be economic costs to protect airports, or potential loss of airport capacity. Storm surges will happen in the nearer term and may impact operations and infrastructure. Ground access may also be vulnerable.

THE CLIMATE IMPACT THE AVIATION IMPACT Sea-level rise in Europe projected to be Permanent or temporary loss of airport around the global average: 0.26–0.54m over capacity and airport infrastructure 21st century for RCP2.6 and 0.45–0.81m Permanent or temporary loss of ground for RCP8.5 (there will be local differences access to airports and some recent studies do suggest higher Economic costs of sea-level and storm surge protection Exception for Europe is the northern Baltic Delay and perturbation from runway Sea and the northern Atlantic: post-glacial inundation rebound is causing land to rise and so sea-Network disruption level rise is lower than in other regions Uncertainty regarding storm surges remains high and there will be regional differences

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Table 5 / The potential impacts of rising sea-levels (Refs. 13, 21, 22, 23, 31)



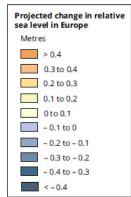


Figure 8 / Projected change in relative sea-level for 2081-2100 compared to 1986-2005 for the IPCC medium-to-low emissions scenario RCP4.5. (Source: EURO-CORDEX (Jacob et al, 2014) in EEA 2017)

Figure 8 shows that although the overall trend is for a rise in sea-level, there will be regional differences with some locations expecting an increase of more than 0.4 metres by the end of the century under the IPCC medium-to-low emissions scenario. Although the impacts of sea-level rise are not expected until later in the century, more frequent or more intense storm surges may have an earlier impact causing flooding and temporarily raising sea-levels (Ref. 13). Analysis by the European Union Joint Research Centre identifies 96 European airports at risk of inundation from one metre of sea-level rise, although it is noted that by taking adaptation measures such as building dikes this should not affect their operations. With a more extreme sealevel rise of between 1 and 3 metres, 23 additional airports may be at risk, although this is at the high end of sea-level rise projections (Ref. 23).

ACTIONS TO ADAPT

For sea-level rise, the longer timescales allow more time for planning based on safety and economic factors. Measures that are implemented will be based on an individual organisation's specific situation, although coordination and collaboration with local government and other local stakeholders may be beneficial. Measures to consider include allowing a certain degree of encroachment of water, as long as safety is not compromised, constructing,

raising or reinforcing sea-defences and existing infrastructure or relocating sensitive or valuable infrastructure. Development of secondary airports, or airport relocation, may also need to be considered in more serious cases. Maintaining ground access links should also be addressed and coordination with transport providers will be required. When developing new infrastructure sea-level rise forecasts should be considered.

An increase in intensity or frequency of storm surges may occur in the nearer term, but adaptation measures will be similar, with the need to consider defence or reinforcement options. Measures to improve flexibility and robustness during operational disruption could also be considered.

STAKEHOLDERS' VIEWS

Whether an organisation is affected by sealevel rise will be dependent on its geographical location, and consequently it will not be a risk for all stakeholders. This is reflected in the survey results by the smaller number of respondents that selected it as one of the main impacts they expect to be affected by. Nevertheless, 13 of the 44 respondents that answered this question cited it as one of the main climate change impacts to address for their organisation.

THE CHALLENGES OF CHANGING WIND PATTERNS

Changes to the jet stream will alter flight times and increase clear air turbulence. Shifts in prevailing wind direction may lead to an increase in crosswinds which can cause changes in procedure or disruption to operations. More research is required.

THE CLIMATE IMPACT	THE AVIATION IMPACT
 Changes to the jet stream (strength, latitude, altitude and curvature) Potential increase in extreme wind speeds for northern parts of central and western Europe, and potential decrease in extreme wind speeds in southern Europe Changes in prevailing wind direction due to movement of the jet stream and storm tracks Strengthening of vertical wind shear 	 An increase in clear air turbulence. Changes to trans-Atlantic flight times and routings Increase in crosswinds due to shifts in prevailing wind direction Changes in procedure due to crosswinds may have an environmental impact. Reduction in capacity at airports with no crosswind runway Disruption to operations if winds are too strong to take-off or land for some aircraft types

Table 6 / The potential impacts of changing wind patterns (Refs. 11, 32, 33, 35)

Changing global wind patterns can alter flight times and increase clear air turbulence (see box "Changing flight times and more turbulence"). However, one area which remains under-explored in the literature is potential changes to local wind patterns, and a possible increase in cross-winds as a result.

STAKEHOLDERS' VIEWS

Changes in wind conditions are one of the physical impacts of climate change which stakeholders expect to be most affected by. They also noted that there may be a possible increase in en-route turbulence.

ACTIONS TO ADAPT

This is an area where more research is required, particularly to understand the implications of shifts in prevailing wind direction. This is an organisation-specific impact which will be dependent on both runway configuration and projected wind patterns, and so a local risk assessment would be beneficial. For clear air turbulence (CAT), technologies for detection are required and changes to airframe design may need to be considered. Improved operational CAT forecasts will increase the pilot's ability to avoid areas of CAT to the extent possible (Ref. 33; Ref. 34; Ref. 35).

- "... Changing wind patterns en-route and turbulence en-route"

 Pilot
- "... Turbulence and surface winds"

 Manufacturer
- "... Cross winds" Service provider

|||||||

Changing flight times and more turbulence

A jet stream is a current of air characterised by both high speeds (up to 320km/h) and strong transverse gradients of speed. Europe is mainly affected by the North Atlantic jet stream, which is formed as a result of a temperature gradient between the cold polar air masses and the warmer tropical air masses (Ref. 36). The direction, position and strength of the winds are not always constant and some evidence suggests that, due to climate change, the jet stream is becoming more variable in position, direction and strength (Ref. 37; Ref. 38).

Changes to the jet stream can have an impact on aviation operations in two main ways; increasing clear air turbulence and impacting flight times. Climate change is expected to strengthen the North-Atlantic jet stream, causing an increase in both the frequency and strength of clear-air turbulence with a potential increase in moderate turbulence by "94% (37%–118%), moderate-to-severe by 127% (30%–170%), and severe by 149% (36%–188%)" along transatlantic flight corridors (Ref. 33, p.576).

Changes to the strength of the jet stream also have the potential to increase westbound transatlantic journey times and decrease eastbound ones. However, the increase and decrease do not counterbalance each other, leading to a mean lengthening of the round-trip journey time, and a corresponding increase in flight time, fuel burn / emissions and costs (Ref. 39; Ref. 40). We have recently seen record Eastbound flight times due to temporarily increased strength of the jet stream (Ref. 41).

We are also starting to get anecdotal evidence that variability of the jet stream, coupled with continuing traffic growth, particularly in intercontinental long-haul flights, is leading to challenges in planning flights and for airports to handle arrivals. Particularly at major European hub airports the earlier than planned arrival of intercontinental traffic can lead to problems with slot management and aircraft needing to hold. This is an issue to monitor for the next Challenges of Growth report in order to assess whether it is going to be a short-term trend or a more permanent challenge.

DIFFERENT IMPACTS, JOINT CHALLENGE

The same impact can affect multiple stakeholders in different ways. However, an integrated and collaborative approach to building resilience is required

The potential climate change impacts for an organisation will vary according to climate zone, location, and type of organisation. For example, with changes in storm patterns, damage to infrastructure from storms may be a key concern for airports, whilst an increase in en-route convective weather may be a bigger concern for aircraft operators. But some impacts can affect multiple stakeholders, for example, changes to the jet stream's strength and location can impact aircraft operators' routings, flight times and fuel consumption; ANSPs' management of en-route capacity; and also airport operators' gate and

stand management if arrival times differ greatly from planned slots. Moreover, disruption in one part of the network can have a knock-on effect for other stakeholders if, for example, runway capacity is temporarily lost at a key hub airport. Therefore, whilst each organisation will take its own adaptation planning decisions to respond to its individual needs, the combined effect of those actions works to build the resilience of the network as a whole: the interconnectedness of the European and global aviation system necessitates an integrated and collaborative approach to building resilience.

Different actors, different impacts

Note that these are selected examples only and the significance of these risks will vary according to climate zone, geographical location and type of operations.



Precipitation change

- Disruptions to operations (e.g. airfield flooding, ground subsidence)
- Reduction in airport throughput
- Inundation of transport access (passengers and staff)
- Loss of local utilities provision (e.g. power)

Sea-level rise

- Loss of airport capacity
- Impacts on en-route capacity due to lack of ground capacity
- Loss of ground transport access

Temperature change

Changes in aircraft performance

Wind changes

- Convective weather: disruptions to operations
- Convective weather: route extensions
- Jet stream: potential increase in en-route turbulence
- Crosswinds: reduction in capacity

Extreme events

- Disruptions to operations
- Disruption to ground transport access
- Disruption to supply of utilities



AIRPORT OPERATORS

AIRCRAFT OPERATORS

Precipitation change

- Disruptions to operations (e.g. airfield flooding, ground subsidence)
- Reduction in airport throughput
- Inundation of transport access (passengers and staff)
- Loss of local utilities provision (e.g. power)
- Inadequate drainage system capacity
- Inundation of underground infrastructure (e.g. electrical)

Sea-level rise

- Loss of airport capacity
- Loss of airport infrastructure

Temperature change

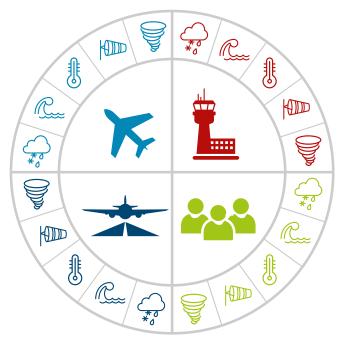
- Changes in noise impact due to changes in aircraft performance
- Heat damage to airport surface (e.g. runway, taxiway)
- Increased heating and cooling requirements

Wind changes

- Convective weather: disruption to operations
- Local wind patterns: potential disruption to operations and changes to
- Crosswinds: reduction in capacity

Extreme events

- Disruptions to operations
- Disruption to ground transport access
- Disruption to supply of utilities





NAVIGATION SERVICE PROVIDERS

Precipitation change

- Disruptions to operations (e.g. airfield flooding, ground subsidence)
- Reduction in airport throughput
- Inundation of transport access (passengers and staff)
- Loss of local utilities provision (e.g. power)

Sea-level rise

- Loss of airport capacity
- Impacts on en-route capacity due to lack of ground capacity
- Loss of ground transport access

Temperature change

- Changes in aircraft performance
- Changes in noise impacts due to changes in aircraft performance

Wind changes

- Convective weather: disruptions to operations
- Convective weather: route extensions

Extreme events

- Disruptions to operations
- Disruption to ground transport access
- Disruption to supply of utilities



AIR

Precipitation change

- Inundation of ground transport access (passengers and staff)
- Loss of local utilities provision (e.g. power)

Sea-level rise

Loss of ground transport access

EXTERNAL

Temperature change

Increased pressure on local utilities (e.g. water and power, for cooling)

Extreme events

- Disruption to ground transport access
- Disruption to supply of utilitie

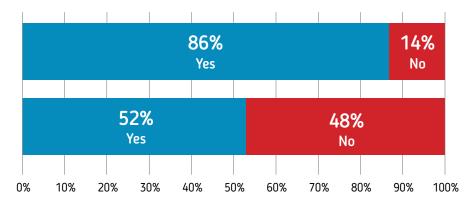
Extreme events: Sudden intense and short-lived precipitation and wind events e.g. storm surges, hurricanes, hail storms, lightning as opposed to seasonal or annual changes. of operations.

ADAPTING EUROPEAN AVIATION TO A CHANGING CLIMATE

Eighty-six percent of respondents expect adaptation to the impacts of climate change to be necessary, and 52% have begun adaptation and resilience planning. Many respondents stated that they have no information on how to plan for adaptation whilst a smaller number consider it too early.

Eighty-six percent of respondents expect adaptation to the impacts of climate change to be necessary now or in the future, the same proportion as in 2013, suggesting that perceptions of climate change risk have, on the whole, not greatly changed, although there may be wider awareness of the issue (N = 91, Figure 10a). However, only 52% of organisations have responded to this by initiating planning for the impacts of climate change (N = 80, Figure 10b). This compares to 48% in 2013. This suggests that even though there is a growing awareness of this issue, there are still reasons for not taking action.

- a) % of organisations that consider adaptation to reduce the potential impacts of climate change may be necessary now or in the future
- **b)** % of organisations that have begun planning for adaptation to climate change impacts



(a) 86% of respondents consider adaptation action may be necessary (b) 52% of organisations have begun planning for adaptation to climate change.

Reasons organisations gave for not initiating planning varied from considering it too early, not having information on how to plan and not having financial resources (Figure 11). Of the 31 respondents that answered this question 15 indicated that they had no information on how to plan and five responded that they were not aware of the need, suggesting that there may be a need for further information and guidance in this area. Eleven respondents answered that it was too early to begin planning, suggesting that for some organisations this is seen as a longer term risk, whilst seven organisations cited lack of resources as their reason for not initiating action.

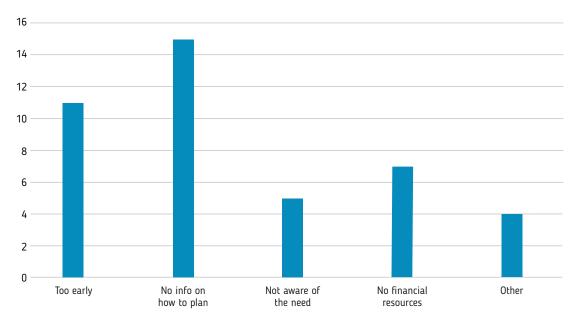


Figure 11 /Organisations' reasons for not initiating planning for adaptation include lack of information or considering it too early.

ASSESSING CLIMATE RISK AND PLANNING FOR ADAPTATION

A climate change risk assessment will identify risks and vulnerabilities which an organisation may need to adapt to. A first high-level look can identify the need for a more detailed assessment.

A climate change risk assessment is a way for an organisation to assess what its risks and vulnerabilities from climate change might be before going on to develop a climate adaptation strategy or plan. To decide whether or not there may be a need to do a risk assessment an organisation can ask a few key questions about how the climate may change locally, or, in the case of airlines, in the locations where they are based and the destinations that they fly to, and the potential impacts this

could have (Figure 12). For example, if an increase in precipitation is forecast, then current drainage systems may not be sufficient, or if temperatures are expected to increase then existing cooling systems may not be adequate. If this high-level first-look flags up potential vulnerabilities, then a more thorough risk assessment may be required, noting of course that carrying out a risk assessment does not lock an organisation into taking further action.

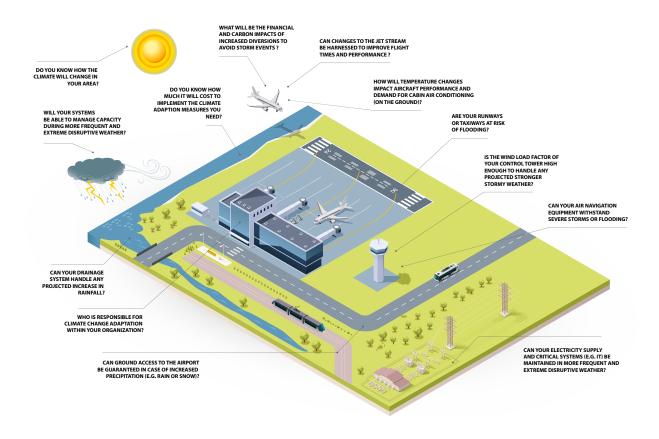


Figure 12 / Getting started with risk assessment: a few key questions (Source, EUROCONTROL et al. 2014)

There are a number of key stages to planning and carrying out a climate change risk assessment, and detailed guidance can be consulted (c.f. Ref. 26; Ref. 42; Ref. 43; Ref. 44). The first steps are identifying how the local climate will change and building the team to carry out the risk assessment. Although climate adaptation is often viewed as the counterpart of climate mitigation, it is not solely an environmental issue as it also creates challenges for operations, infrastructure, safety, business and mobility. Therefore it is important to identify all of the areas in an organisation which need to be involved, as well as coordinating with partner organisations. Senior management buy-in will also be essential. As the impacts and adaptation measures required will be specific to the organisation's climate zone, geographical location and type of operation it is important to work with forecasters to understand how the local climate might change.

A climate change risk assessment can be carried out using an organisation's existing risk assessment methodology, or an organisation may choose to develop its own climate risk assessment methodology, or use one developed by another organisation. It is also important to identify whether there is any local, national or regional legislation that needs to be complied with.

Decisions on which adaptation actions to take will be highly dependent on local circumstances and business models. Pre-emptive action is widely judged to be beneficial and cost-effective, reducing both costs and damages in the longer term, but it should be based on the best available information to avoid excessive or inappropriate adaptation. "Low-regrets", "no-regrets" or "win-win" measures are widely considered to be cost-effective. These are measures that are intended to address another issue such as capacity, and which also help to build resilience. Soft measures such as training are also important to make sure staff are ready to address potential challenges. Communication and collaboration locally, regionally and globally, and across sectors, will be required to develop the overall resilience of the network.

CURRENT ADAPTATION STATUS OF THE EUROPEAN NETWORK

A growing number of stakeholders consider that both the European aviation sector and European ATM are taking measures to adapt to climate change, but that more needs to be done.

Stakeholders consider that both the European aviation sector and European ATM are becoming better prepared to deal with the potential challenges of climate change. Over half of respondents to this question (55%) think that the sector has some adaptation measures in place but that more needs to be done (N = 63, Figure 13a). This compares to 50% in 2013. Just 6% of respondents think that the sector has not considered adaptation, compared to a much larger 25% in 2013. More specifically for European ATM, 60% of respondents consider that some adaptation measures are in place (N = 50,Figure 13b). Compared to 31% in 2013, this would suggest that progress is indeed being made. 8% consider that European ATM has not considered adaptation, a big decrease from 25% in 2013.

It is clear that awareness is growing and more organisations are taking action. However, consideration needs to be given to whether sufficient measures are being taken quickly enough, or whether we need to accelerate action.

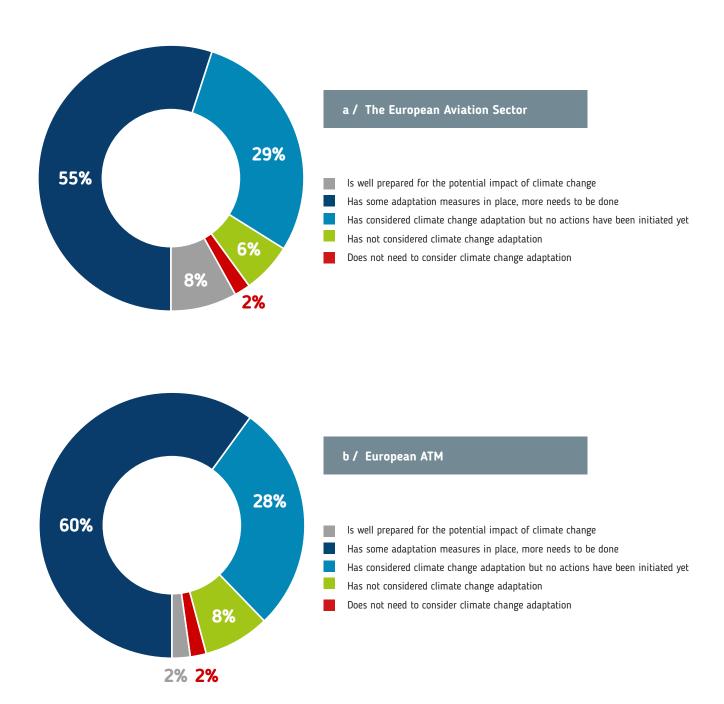


Figure 13 / Stakeholder perceptions of level of preparedness for the potential impacts of climate change for (a) the European Aviation Sector as a whole (b) European ATM.

STAKEHOLDERS' VIEWS

There was a general consensus from survey respondents that awareness of this issue is rising and that there is more information available now. Many stakeholders noted that there is work going on to identify and assess impacts, but more research is required; in particular more research on in-flight icing conditions, turbulence, surface winds, humidity conditions and the frequency and intensity of lightning strikes was proposed.

Stakeholders stated that more needs to be done to translate the information that is available into action. It was highlighted that translating the science into impacts and costs is required as making it tangible will promote action and facilitate senior management buy-in. They also observed that there are different levels of preparedness within the sector and that some organisations are moving faster than others. Some stakeholders noted that the sector as a whole does not seem to be working very actively on this issue and that more could be done at sector-level; for example: risk assessment, action plan or road map development, developing suggested action lists for different types of organisations, and more general support and communication. The need to make sure we are all planning for the same future scenario was also identified.

Several respondents identified a good risk assessment as the basis for effective adaptation action. Building climate resilience into business plans and taking a longer-term perspective was also proposed. The need for increased communication, collaboration and coordination among stakeholders and at sector-level was continually highlighted, as was the need for more support such as training, workshops and guidance. Overall, most respondents agreed that some action is being taken, but that not only does more need to be done, it also needs to be done more quickly so that as a sector we do not get caught unprepared.

- "... Awareness about the potential impacts of climate change on aviation is growing."

 Manufacturer
- "... New infrastructure appears to be being built with climate change in mind but there remains much legacy infrastructure that may be susceptible to greater extremes."

 CAA/Regulator
- "... Gathering and assessing information, and research on impacts is necessary."

 Pilot
- "... Improve awareness, share experience, training."

ANSP 200,000 – 499,999 flights per annum

- "... Build climate resilience into business plans." CAA/Regulator
- "... Be more proactive in the implementation of measures rather than being caught unprepared."

Airport Operator - 100,000 – 249,999

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STAKEHOLDER ACTIONS TO ADAPT

A growing number of organisations have climate adaptation plans in place. Planned adaptation measures include preparing for changes to temperatures and precipitation, contingency, business and infrastructure planning.

Decisions on which adaptation actions to take will be highly dependent on local circumstances, expected changes to the climate, and business models. Measures may be operational, financial or be intended to make infrastructure more resilient. Seventeen of the organisations that responded to the survey already have a climate change adaptation plan in place. However, this question was not mandatory and only a third of respondents answered it, therefore this may not be a complete representation of the number of organisations in Europe with plans in place. In general, there does seem to be a move towards more organisations developing plans, particularly airport operators and regulators.

Figure 14 gives an overview of measures already being implemented, or considered, by those organisations that have an adaptation plan in place. Most respondents are taking measures to prepare for the impacts of changes to temperatures or precipitation, which is consistent with these impacts being viewed as the biggest risks. Contingency planning for operational resilience and to deal with unexpected disruption, as well as business and infrastructure measures, are also viewed as important. Other measures that were highlighted were staff engagement, building climate change forecasts into capital investment projects and updating environmental management systems and risk assessment processes to incorporate impacts from climate change.

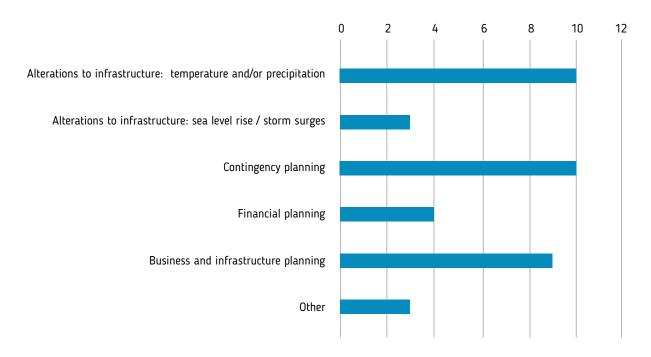


Figure 14 / Measures which organisations are taking or expect to take develop climate resilience.





CONCLUSIONS

Scientists are certain that the climate is changing. Over the medium and longer term, there will be changes to temperatures, to rain, snow, wind and storm patterns and in the sea-level. This will affect aviation infrastructure, daily operations and, more uncertainly, patterns of demand. An updated and re-run stakeholder climate change adaptation survey received a much larger response than in 2013 - over 90 respondents - and shows that the European aviation industry increasingly recognises that these challenges are coming. Over a quarter of respondents are already experiencing the impacts of climate change and, talking to our operational stakeholders, many already report seeing changes in regular weather patterns, such as more frequent and intense disruptive weather events, that impact their operations. Organisations expect an increase in extreme weather, higher temperatures, changes in wind conditions and increased precipitation to be the biggest challenges they will have to face.

Despite this growing awareness, there has been little change over the last five years in the proportion of organisations actually planning for adaptation to climate change impacts. Only a small majority (52%) reported that their organisations had begun to plan for adaptation compared to 48% in 2013; but as the response size was much smaller last time the actual number of organisations taking action is greater. Reasons for not taking action include lack of information and lack of resources, and considering it too early.

One of the themes of Challenges of Growth is sounding an early warning, leading to actions that are taken in good time. Given the long-term horizons of investments in aviation infrastructure, some of these climate change effects are within planning horizons, e.g. before 2040. We therefore need to do more here to understand the gap between recognising the need and real planning for action: are we acting sufficiently and in sufficient time? If not, what can be done to encourage investments that take climate change into account? Individual organisations will of course take their own adaptation planning decisions based on their own specific circumstances and business decisions. However, due to the interconnectedness of the European and global aviation system an integrated and collaborative approach to building resilience is required. This a risk that needs further investigation.

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