Chapter 6

ADAPTATION

ICAO
ENVIRONMENTAL
REPORT 2010

Aviation and Adaptation to Climate Change

Overview

By ***ICAO Secretariat***

Climate change is considered to be one of the most serious environmental threats to sustainable development, with adverse impacts expected on human health, food security, economic activity, natural resources and physical infrastructure. There is solid scientific evidence to suggest that despite the technology improvements as well as other operational and economic measures to reduce greenhouse gas (GHG) emissions, the climate could continue to change, and the potential consequences might be significant.

The likely impacts of climate change (storms, heat waves, etc.) were initially assessed by the Intergovernmental Panel on Climate Change (IPCC) in 1999 and these assessments have since been updated, the most recent one being IPCC's Fourth Assessment Report issued in 2007. According to the latest IPCC assessments, the impacts of climate change will be felt worldwide (see article *Adaptation to Climate Change – Challenges Facing Civil Aviation Stakeholders*, Chapter 6 of this report). The need to address the adverse effects of climate change either by mitigation or by adaptation is becoming more pressing.

The articles in Chapter 6 of this report focus on how the changes in climate could affect aviation and the possible areas where aviation might need to adapt its ground and flight operations.

Adaptation - An International Concern

The Bali Action Plan adopted in 2007 at the thirteenth Conference of the Parties (COP13) of the United Nations Framework Convention on Climate Change (UNFCCC), identified "adaptation" as one of the four building blocks (along with mitigation, finance and technology) required for a strengthened future response to climate change. These building blocks are meant to enable the full, effective and sustained implementation of the UNFCCC through long-term cooperative action, from now to beyond 2012.

Most recently, in 2009 at COP15 held in Copenhagen, the UNFCCC Parties stressed the need to establish a comprehensive adaptation programme. It was agreed that enhanced action and international cooperation on adaptation is urgently required and that the developed countries should provide adequate, predictable and sustainable financial resources, technology, and capacity-building to support the implementation of adaptation actions in developing countries[1]. Adaptation to the effects of climate change is now acknowledged as necessary for responding effectively and equitably to the impacts of climate change.

Adaptation versus Mitigation

The terms "adaptation" and "mitigation" describe two actions that are essential in the climate change area. From its beginning, the international climate effort has focused primarily on "mitigation" — reducing GHG emissions to address climate change. However, in recent years, more attention is being given to "adaptation" – adjusting to and dealing with the impacts of climate change. The inset box provides more formal definitions of climate mitigation and adaptation. While mitigation addresses the causes of climate change, adaptation addresses the effects of the consequences. Obviously, better mitigation, because of its proactive nature, reduces risks at an early stage and therefore lessens the need for adaptation. Similarly, early recognition of climate change and anticipation of its impacts will be essential for adjustments in the future. This early preparation will reduce the impacts to any given degree of climate change.

__Climate mitigation__ can be defined as actions taken to stabilize or reduce GHG concentrations in the atmosphere. The IPCC defines mitigation as "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases"[2]. An example of a typical mitigation measure for aviation would be optimizing the air traffic management systems to enable more direct routings and therefore reducing GHG emissions.

__Climate adaptation__ refers to the ability of a system to adjust to climate change to moderate potential consequences or to manage the consequences of those impacts that cannot be avoided[3]. The IPCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploits beneficial opportunities"[4]. Successful adaptation can reduce vulnerability by strengthening existing strategies. A typical case of adaptation for aviation would be improvements in coastal area airports' defences against sea level rise.

Adaptation and Aviation

While drastic reductions in emissions through mitigation measures could stabilize atmospheric GHG concentrations at low levels, it is expected that they will be above the current levels in a few years. With higher concentrations, new phenomena will be observable such as a rise in temperatures and sea level, changes in precipitation, and more extreme weather as shown in Figure 1 (see article *Adaptation to Climate Change – Challenges Facing Civil Aviation Stakeholders*, Chapter 6 of this report).

IPCC predicts a rise in mean sea level between 0.6 feet to 1.9 feet by 2100.

Anticipation of and adaptation to these impacts are vital to ensure a reduction in the magnitude of consequences of climate change. The impact of temperature and precipitation changes could increase the demand for cooling for buildings or increase the drainage requirements for runways. These are only some potential effects among others (see article *Adapting to Climate Change at Airports*, Chapter 6 of this report). Some limitations for ground and flight operations have

	Level of Uncertainty	Probability of Occurence
Sea level rise	Virtually certain	≥ 99%
Temperature changes		
Decreases in very cold days	Virtually certain	≥ 99%
Increases in Arctic temperatures	Virtually certain	≥ 99%
Later onset of seasonal freeze, earlier onset of seasonal thaw	Virtually certain	≥ 99%
Increases in very hot days and heat waves	Very likely	≥ 90%
Precipitation		
Increases in intense precipitation events	Very likely	≥ 90%
Increases in drought conditions for some regions	Likely	≥ 66%
Changes in seasonal precipitation and flooding patterns	Likely	≥ 66%
Storms		
Increases in hurricane intensity	Likely	≥ 66%
Increased intensity of cold-season storms, with increases in winds, waves and storm surges	Likely	≥ 66%

Less certainty

IPCC 2007. Summary for Policymakers. In climate Change 2007: The Physical Science Basis.
Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

***Figure 1:** Potential likelihood of need for adaptation measures (IPCC 2007 Summary for Policymakers in Climate Change 2007).*

already been noticed in Europe. These include high wind events, freezing rain, heavy precipitation and lightning strikes (mainly in summer) that can threaten buildings, facilities, and aircraft. Similarly, in winter, there are challenges associated with snow prediction and removal (see article *European ATM and Climate Adaptation - A Scoping Study*, Chapter 6 of this report).

The impacts of climate change will be more visible in low lying coastal areas in terms of sea levels and storm activities. Infrastructure such as runways and buildings at some airports could be impacted because of rising sea levels (see article *Adapting to Climate Change at Airports*, Chapter 6 of this report). According to a preliminary review of an OECD Report[5], 64 airports have been identified as likely to be affected by the predicted rise in sea levels. In view of the risks to major coastal cities, as indicated in the IPCC report[6], flooding and storm activities could impact movement of aircraft and travellers adversely. In addition, possible damage to infrastructure on the air and land side of the airports should be considered. Even though there are some uncertainties about the potential impacts of climate change on aviation operations and related infrastructure, clearly there are challenges that will need to be addressed.

Conclusions

Adaptation to climate risks may take the form of specific actions or projects, for example, construction of a sea wall to protect areas from rising sea levels, or establishment of an early warning system for potential flooding or heat waves. These solutions will require significant investments. States are becoming increasingly aware of the potential risks associated with climate change and will have to incorporate these risks into their future planning, such as for airport development, and design their adaptation strategies accordingly.

While ICAO has shepherded improved aviation environmental protection since the 1960s through development of standards and recommended practices, it is aware that additional ambitious mitigation efforts are still needed. The Organization recognized the need to also consider adaptation since the consequences of climate change need to be anticipated and effectively addressed. ■

REFERENCES

1 *United Nations Framework Convention on Climate Change website*
http://unfccc.int/adaptation/items/4159.php

2 *IPCC Third Assessment Report website*
http://www.grida.no/publications/other/ipcc_tar/

3 *http://www.global-greenhouse-warming.com/climate-mitigation-and-adaptation.html*

4 *Glossary of Terms used in the IPCC Fourth Assessment Report*

5 *OECD Report on the Ranking of the World's Cities Most Exposed to Coastal Flooding Today and in the Future*

6 *IPCC Fourth Assessment Report*

Adaptation to Climate Change

Challenges Facing Civil Aviation Stakeholders

By ***Herbert Puempel***

Herbert Puempel *is currently the Acting Director of the Meteorology Branch, Weather and Disaster Risk Reduction Services (WDS) Department at the World Meteorological Organization (WMO), and has been Chief of the WMO's Aeronautical Meteorology Division since 2006. In addition, Dr. Puempel has been a member of the Commission for Aeronautical Meteorology since 1991, and the WMO Observer to the ICAO Committee on Aviation Environmental Protection (CAEP) since 2000.*

Dr. Puempel obtained his PhD in Meteorology and Physics from the University of Innsbruck in 1978, undertaking his studies in the fields of theoretical physics, dynamic meteorology and Spanish translation.

Introduction

Climate change and variability are subjects of intense study and discussion, not only in the scientific community but also in different sectors of the economy. The issue poses major challenges to political and economic bodies and decision-makers. Through its various programmes, the World Meteorological Organization (WMO), which represents 189 Member countries and territories, has addressed these questions since the emergence of observational and theoretical evidence. Most recently, the WMO hosted the third World Climate Conference in September 2009 in Geneva, which involved participation of scientists, major economic bodies, and high-level decision-makers from national governments and international organizations.

The Conference culminated in the creation of a Global Framework for Climate Services with the aim to contribute to the assessment and reduction of climate and weather related risks to all societal sectors, including transportation. The scientific community is now realizing the need to investigate possible ways to adapt to climate change and it is understood that this issue is no longer fundamentally in question. Nevertheless, it is recognized that some remaining issues such as the effects of contrails and cirrus, and possible avoidance and trade-offs, still require major research and operational efforts (see Figure 1).

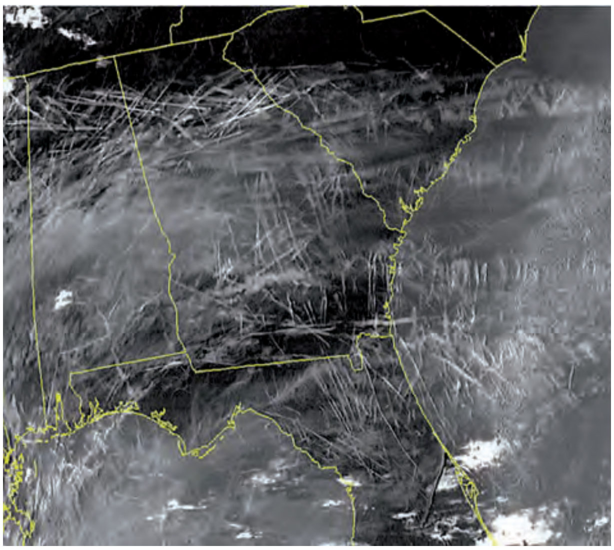


Figure 1: *Satellite imagery of contrails over Eastern North America.*

The implementation of a range of new climate-related services will be essential if those building and operating transport systems are to make the best decisions. Furthermore, decisions made at one particular time, on the basis of the best available information at the time, will need to be constantly re-evaluated. In essence, an adaptive management approach, underpinned by a Global Framework of Climate Services (GFCS), will need to be:

- Accessible to all parties; since climate variability has a potential impact on economic decisions, this information must be openly available.
- Driven by ongoing research, and building on existing collaboration between the meteorological and transport communities dealing with chronic risks.
- Continuously improving forecasts, in particular for specific regions and locations, and expressed in a clearly understandable way to decision-makers.
- Improving the range, availability and accessibility of information through exchange of data between research and operational agencies for the Earth, atmospheric and oceanic systems.
- Creating information that facilitates accessibility and mobility options that are robust in terms of climate variability and that considers mitigation, including travel related to tourism.

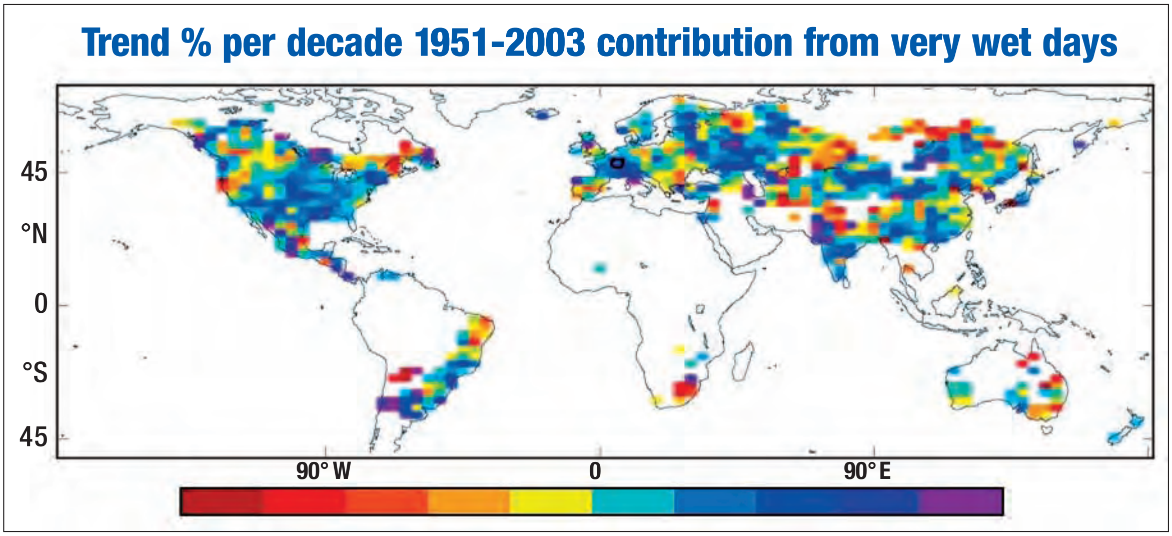
Climate Change and Variability – A Scientific Challenge

While the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) provided a fairly robust global trend for surface temperatures, and to some extent also precipitation, specific scenarios on a regional and local basis will require considerable further efforts before they can be translated directly into critical information for decision-makers.

Far from a uniform shift to higher temperatures and changed annual rainfall amounts, observational evidence and results of higher resolution model runs and downscaling exercises appear to indicate that extremes of temperature, wind and precipitation are likely to become more frequent. Also indicated is that the duration of significant events (i.e. heat waves, droughts, etc.) may see noticeable changes. In some regions such as the Mediterranean and the southern European area, the contribution of strong and extreme rainfall events to the annual precipitation total has been seen to increase over recent decades.

Analysis of Figure 2 reveals the following: **Upper:** Observed trends (%) per decade for 1951–2003 for the contribution to total annual precipitation from very wet days corresponding to the 95th percentile.

Middle: Anomalies of the global annual time series of very wet days (with respect to 1961–90) defined as the percentage change from the base period average (22.5%). The orange



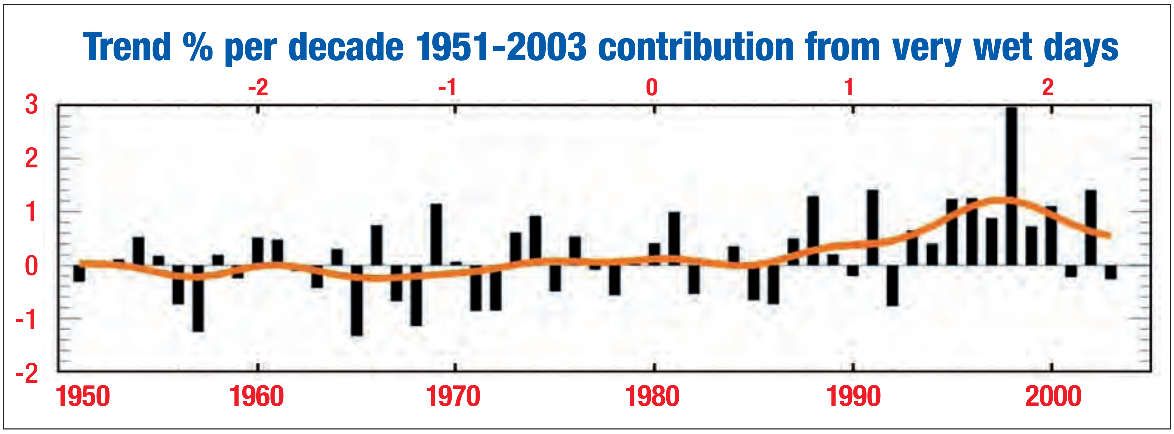


Figure 2: *Worldwide precipitation trends, by decade, 1951 to 2003 (Technical Summary IPCC WG1 Fourth Assessment Report).*

line shows decadal variations. **Lower:** Regions where disproportionate changes in heavy and very heavy precipitation during the past decades were documented compared to the change in the annual and/or seasonal precipitation. Thresholds used to define "heavy" and "very heavy" precipitation vary by season and region.

While it may be tempting to assume a general trend toward higher temperatures, and that problems related to snowfall and low temperatures may become rare and less disruptive to transport systems, it appears that high variability will be the more likely scenario. Several winters with short periods of snow cover and milder temperatures are often countered by very severe and long-lasting events.

Operational Challenges of Weather and Climate Extremes

The current relevant publication from WMO on detecting significant changes is WMO Technical Document No. 1500: "Guidance on Analysis of Extremes In A Changing Climate In Support of Informed Decisions For Adaptation". It highlights the difficulties faced by operational meteorological and climatological services in providing the required information, as follows: "For the moment, it remains difficult to detect significant changes in many types of extremes because of the limited amount of available observational information. This is because extreme events are rare by definition, and because observational records, where available, are often not long enough. It should be noted that a failure to detect a significant trend indicates there is insufficient information to reliably identify change, but this does not necessarily mean that there is no change or that the likelihood of a given type of extreme event has not been affected by other changes that have been observed in the climate system."

Considering the need to incorporate climate information and trends into planning and operation of vital transport infrastructure, experts in climate and transport have recommended the following principles and approaches:

Climate resilience: Planning and design of transport infrastructure needs to account for climate uncertainties to enable more resilient responses to climate change. Typical examples would include adaptation of runway construction and airport infrastructure to anticipated temperature changes (important for the density altitude[1] and thus required take-off length). Issues will include: the anticipation of sea level rises and storm surges for coastal airports, anticipated possible changes in the severity and frequency of severe storms (in particular tropical storms), and anticipated changes in maximum wind speeds and gusts. As another example, the changes to permafrost soils may need to be assessed and incorporated into the design of runways in polar and arctic regions.

Multi-disciplinary cooperation: Information sharing and cooperation among professionals in meteorology, hydrology, engineering, statistics, ecology, biology, economics and financial management, and the wider community as well.

Whole-of-life approach: Typical transport infrastructure has a planned lifecycle of several decades to a century, over which a realistic appreciation of expected climate conditions is necessary to protect the users, the infrastructure and the investment.

Risk assessments: Potential risks and cost-benefit analyses of adaptive and mitigation strategies need to be updated regularly in light of emerging evidence of change.

Extreme events: Strengthen emergency response planning and management to respond to extreme events.

Special Vulnerability Considerations of Complex Systems

Global economies are becoming increasingly dependent upon reliable transportation systems. In many cases, fast and efficient transport of goods can replace the traditional storage necessity for such commodities as parts, primary material for manufacturing, food and other essential goods such as medication, IT components, as well as intermediate products. Accordingly, the dependability and resilience of transport is becoming key to uninterrupted essential production and supply chains.

Multi-modal transport systems, where individual sub-modes are no longer able to compensate for a breakdown in one transport mode, suffer from a complex vulnerability to extreme events. A timely example of this is the eruption of the Eyjafjall Volcano in Iceland, which led to a complete shutdown of the European Air Transport System for up to 5 days in April 2010, followed by several shorter and more localized episodes of related traffic disruption. During that outage, it became clear that the remaining modes of transport did not have enough spare capacity to make up for the lack of air transport, which resulted in extremely wide-ranging economic consequences.

As some meteorological, climatological or hydrological phenomena are likely to affect several modes of transport simultaneously, such as major floods or widespread heavy snow or freezing rain, the challenge to the meteorological and climatological community will be to provide a seamless, user-oriented service that supports vital decisions by industry, infrastructure maintenance units and traffic authorities. The decision-making information required by those authorities will range from the tactical (i.e. required in minutes to hours), to strategic (i.e. required in days to weeks), to that needed for long-term planning purposes, which can range from seasonal to multi-decadal time frames.

Specific Considerations - Aviation Operations In A Changing Climate Regime

As mentioned earlier, the detailed effects of climate change on different weather regimes continues to pose a serious challenge to climate science. The atmospheric phenomena with the highest impact on aviation tend to be caused by the smallest scales of motion[2] in the atmosphere. Large-scale changes, such as a slow pole-ward drift of the mid-latitude jet streams, can be fairly easy to accommodate in the short term by adjusting route planning and frequency. However, severe critical events such as microbursts due to severe convection, or runway flooding in similar events, will probably be affected by a large degree of uncertainty for some time to come.

Similarly, climate-change related variations in boundary-layer effects such as fog and low ceilings, as well as questions of local air quality may require significant further study to be fully included in adaptation planning processes. Questions about air quality may re-emerge in some densely populated areas following studies now planned to examine the effects of the complete air traffic shut-down that took place during the recent volcanic ash crisis in Europe. ■

REFERENCES

1 ***Density Altitude*** *is a term used by ICAO and WMO to represent the altitude where the observed air density, vital for calculating the necessary take-off distance, would be in the Standard Atmosphere. It increases with every degree Celsius measured at the runway level.*

2 *Small motions such as turbulence, microbursts, wake turbulence which happen at a scale of tens to hundreds of meters, etc.*

European ATM and Climate Adaptation

A Scoping Study

By ***Alan Melrose***

Alan Melrose *has 38 years experience in environmental management in a wide range of private and public sector organisations. Establishing Manchester Airport's Environmental Control Department in 1988, he was actively involved in delivering Manchester's Second Runway and helped to secure several 'world firsts' in environmental management.*

Alan joined EUROCONTROL 9 years ago and leads projects including the Continuous Descent implementation initiative, Collaborative Environmental Management roll-out and environmental training. Alan supports various ICAO activities including the development of CDO guidance and is a task leader in CAEP Working Group 2 including chairing the Independent Expert Operational Goals Group.

This article is based on a study undertaken for EUROCONTROL jointly by the UK MET Office, The OMEGA Project, and Manchester Metropolitan University. The complete study will soon be available for free download at ***www.eurocontrol.int.***

Background

It is currently estimated that aviation produces about 3% of human-produced emissions. While it is important that the aviation industry does everything it can to reduce greenhouse gas emissions, the rate of climate change is unlikely to be significantly influenced by aviation's efforts alone. Many scientists are now predicting some level of global warming, even if society stopped emitting tomorrow, which is unlikely. Some climate change impacts are being felt by society now (e.g. eco-system changes) and other impacts (e.g. flood damage) could manifest within the asset-life of recent and future major infrastructure development.

This consideration of how the climate may affect economies, business, and society, and how these sectors should respond, is known as "climate adaptation". The anticipated effects of climate change relating to temperature increase are shown in Figure 1 taken from the UK Government funded *Stern Review*.

The critical temperature change threshold seems to be between 2-4 degrees Celsius, warming much above 2 degrees Celsius may trigger other natural climate changes and conditions that society cannot control. Some scientists are now predicting that climate change from humans' historical emissions could be around 1-3 degrees Celsius, without factoring in any present or subsequent emissions. In fact, a 4 degree Celsius temperature rise is now regarded by some climate scientists as being the most likely future scenario. Figure 1 indicates that this outcome is likely to lead to some dramatic impacts on human activities, including aviation.

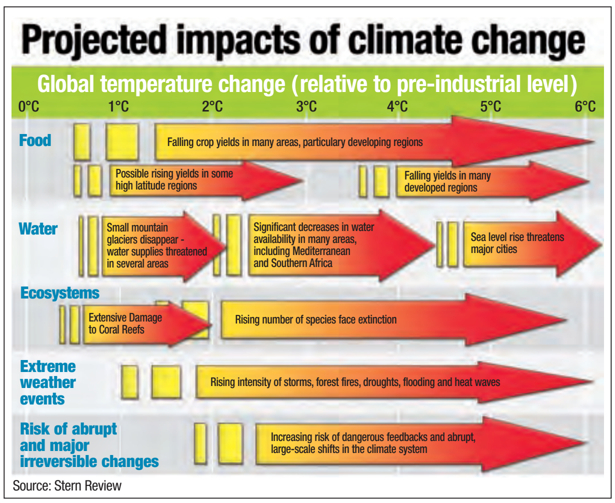


Figure 1: *Projected impacts of global temperature change.*

Operationally, aviation is one of the most climate/weather sensitive industries. It is affected by changes to visibility, storminess, temperature, icing events, flooding events, and the operational effects of these such as changing demand patterns, availability of runways, etc. So far there has been limited research into the potential impacts of climate change on aviation operations. One exception to this is a national study undertaken by Norway (all sectors) that includes a section on the potential impacts of climate change on the Norwegian air transport system (NTP (2007): "Nasjonal transportplan 2010-2019. Virkninger av klimaendringer for Transportsektoren").

It is important to note that Air Transport Management is an integrated system, and as such, an impact in one part of the system can affect all other parts of the system. We have all recently witnessed the system wide effects of the Icelandic volcanic ash event. But such events are not new; Figure 4 shows the European Civil Aviation Conference (ECAC) effects of a temporary unplanned runway restriction at one airport.

EUROCONTROL Climate Adaptation Study Overview

In 2008, EUROCONTROL updated its Challenges of Growth (CoG) study as it does every few years. That study identifies and quantifies the main risks to the European ATM system's ability to accommodate forecast growth in demand and is widely used to inform industry forecasts and development plans. The CoG report includes a section on environment that was previously centred around environmental constraints on airports. In this most recent update however, the additional question was asked – *'what happens if the climate changes despite efforts to control emissions as some scientists are predicting?'*

Since interest in this topic has grown rapidly, the ICAO Colloquium on Aviation and Climate Change allocated an entire session to Climate Adaptation.

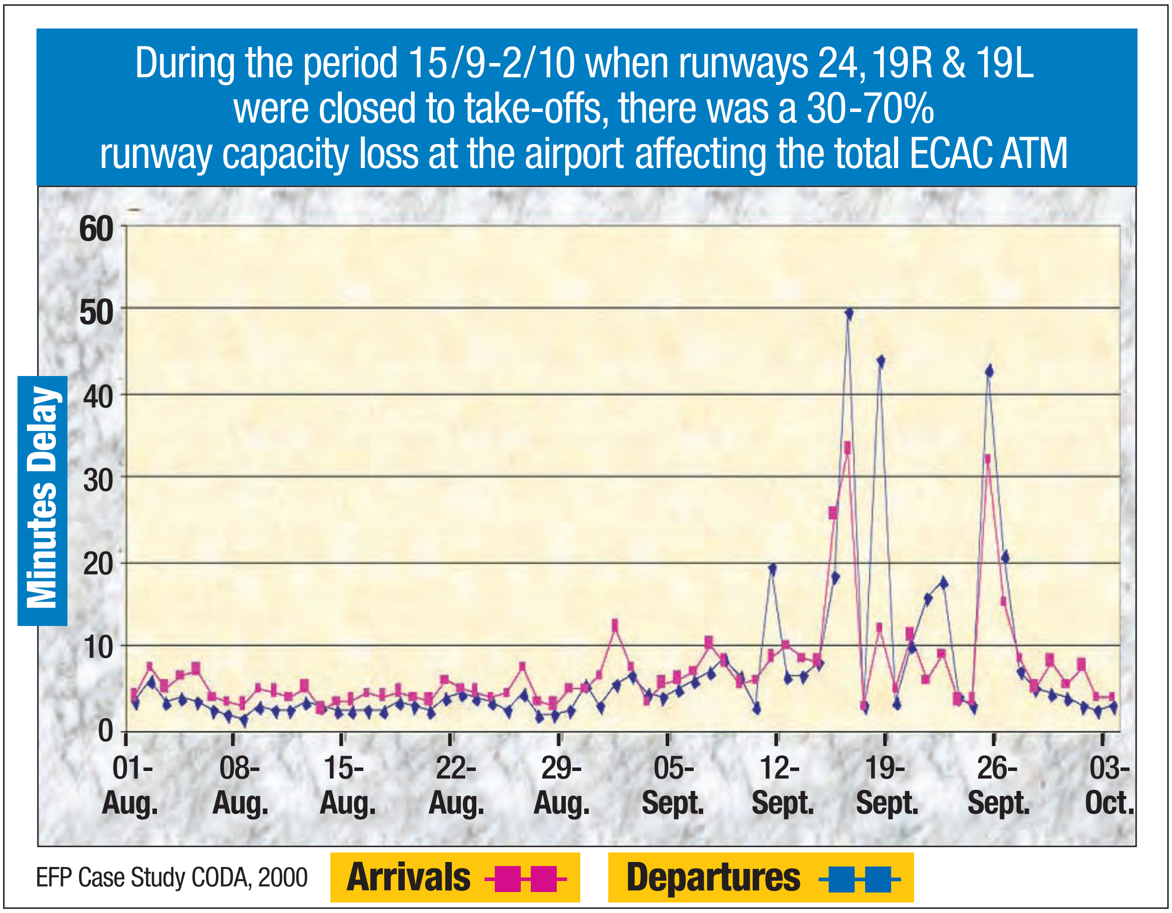


Figure 4: *Effect of some runway closures on entire ECAC ATM system.*

Potential Effect	Primary Climate Change Effects	Confidence / Likelihood	Possible ATM Impacts
Temperature change	• Higher mean temperatures, especially in winter for N. Europe and summer for S. Europe. • Higher, colder tropopause	**High:** Long observational record of temperature increases, all studies considered concur on further increases and in patterns of regional and seasonal change.	• Demand re-distribution (geographical) • Demand peak redistribution (seasonal) • Airport and runway demand mismatch • Airspace capacity and demand mismatch • Optimal cruise altitude changes • Airspace design changes • Traffic flow management issues • Aircraft performance changes • Possible runway length issues • Possible fuel load/yield and range issues • Possible increase in noise contours due to reduced climb performance
Snow & frozen ground	• Fewer days of snow/frost (especially Alpine, Scandinavia, N. Baltic).	**High – Medium:** All regional models considered showed same broad level response, but are driven by the same global model. Regional model projections concur with independent studies.	• Demand re-distribution (e.g. winter sports) • Reduced de-icing and snow clearance requirements • Increased de-icing and snow clearing requirements due to loss of 'white runways'
Precipitation and water supply	• Increased precipitation in N. Europe: winter flooding • Decreased precipitation in S. Europe: summer water shortages	**High – Medium:** All studies considered agree on large scale regional and seasonal patterns of precipitation change but not on exact magnitude. All studies considered indicate future increases in intensity and frequency of droughts for Southern Europe. Exact magnitude of change remains uncertain due to concerns over soil parameterization in regional climate models.	• Demand re-distribution • Demand re-distribution (geographical) • Demand peak redistribution (seasonal) • Airport and runway demand mismatch • Airspace capacity and demand mismatch • Loss of Airport availability and hence perturbation and delay
Sea level	• Increased mean sea level • Increased impacts of storm surges and flooding	**High – Medium:** All studies considered concur that European sea levels will continue to rise. Questions remain over exact local extent of sea level rise due to regional influences such as El Niño. Confidence in changes to extreme water levels is lower than that for sea level projections due to fewer studies and the dependence on changes in the storm track, which are uncertain.	• Demand re-distribution • Loss of Airport availability (over 30 potentially at risk in ECAC) • Loss of ground access to airports • Major economic costs from events and from providing protection • May require public economic support for ground transport infrastructure protection • Delay and perturbation • Some airports may become less viable • Knock-on impacts for diversion airports
General	• The summation of the above	**Medium:** Some high impact risks have medium high confidence in their probability. Timing however is perhaps less certain.	• Borrowing capability • Business case certainty • Route development issues • The appropriateness of major plans as presently designed (e.g. SESAR) - planned ATM performance improvements may already be aligned with this challenge?
Jet stream	• Jet stream changes: movement poleward and upward	**Medium – Low:** 11 of the 15 models considered agree on continued pole-ward movement of storm tracks. Exact changes in storm frequency and intensity remain uncertain due to uncertainties in the detailed model physics needed to represent these changes accurately.	• Changes to storm tracks and hence location of possible weather disruption • Wind strength and direction changes at surface • Possible flow management and airspace design changes
Convective weather	• Increased intensity of precipitation events, lightning, hail and thunderstorms	**Medium – Low:** Severe convection results derived from changes in occurrence of related phenomena, such as intense precipitation events. Uncertainty surrounding modelling of convection and a limited number of studies give low confidence in exact magnitude of change.	• Increased convective weather disruption and delay • Potential safety issues if storminess number and severity increase or predictability reduces
Visibility	• Decrease in winter days affected by fog	**Low:** Fog and haze are boundary layer features not well represented by climate models due to their coarse resolution. There are no studies outside those of the Met Office Hadley Centre so although results from a single model study are plausible they are not necessarily reliable and should not be generalised.	• Fewer capacity restrictions due to reduced visibility • Reduced business case for low-visibility related technologies

Table 1: *Potential climate change effects and their possible impacts on ATM operations.*

Main Findings

As with any new challenge to the aviation industry, stakeholders have legitimate concerns about how this risk is presented. It is important not to raise unnecessary fears or trigger responses that are unnecessary or out of proportion to the risk involved. Until the risks are clarified, any response to this challenge must be considered as speculative. The likelihood, timing, and impact of climate change on the European ATM system will depend on the extent of temperature change as well as on society's ability to reduce emissions of greenhouse gases. Although still uncertain, some scientists believe that certain aspects of climate change are already affecting us. The potential climate effects on air transport are summarized in Table 1, which has been synthesised from the EUROCONTROL report, and in light of subsequent discussions on this topic.

Government Responses To-Date

Climate adaptation is already on the political agenda for some Governments. For example the Nordic States have considered climate impact risk (including aviation) for the last 10 years. In the UK, the Government enacted its first Climate Change Act into law. So there is aviation and transport related climate adaptation related information out there but it is typically on a State by State basis. Information of an ATM system-wide nature however is less mature; ICAO's recent study on the safety implications of Climate Change being a notable exception (http://atwonline.com/eco-aviation/article/climate-change-may-impact-aviation-safety-icao-warns-0517).

Conclusions

Based on the information uncovered for the EUROCONTROL climate adaptation study the author of this report concludes:

- Some level of climate change now seems to be inevitable despite efforts to minimize emissions. As a weather and climate sensitive industry, this could have significant operational and planning implications for air transport in the medium-longer term – and not just for safety.
- Currently, this issue sits in the environmental domain because of its cause - and yet this is really a social, business, economic risk and critically an operational issue - it is therefore a true sustainability issue that cuts across all aviation domains and should not be considered to be primarily an 'environmental' issue.
- Aviation is perhaps lagging behind other industry sectors in understanding and responding to this issue. Banks and insurance companies could potentially raise this issue on the air transport industry agenda at any time. It may therefore be prudent for aviation to develop sufficient knowledge to allow a meaningful dialogue when major planning or investment decisions are being made.
- A new focus on climate adaptation however does not diminish the need to mitigate the aviation industry's climate related emissions or fuel costs.

It is possible that ATM system-wide aviation performance planning is already fully aligned with the potential operational risks from climate change, and that nothing more needs to be done. The truth is however, we just don't know. We must therefore continue to closely monitor all developments related to the issue of the impact of climate change on aviation reacting in a timely and appropriate fashion. Indeed since climate change related impacts form a potential risk to global mobility, crucially including aviation, perhaps society should proactively seek to understand this further – and perhaps governments should fund appropriate global aviation research, with the aviation sector itself playing a central and supporting role. ■

Adapting to Climate Change at Airports

By ***Xavier Oh*** and ***Olav Mosvold Larsen***

Xavier Oh *has been the Environment Manager at ACI since September 2005 and is based in the ACI Montreal Bureau, located near ICAO Headquarters.*

As an industry association, ACI is an official Observer at ICAO's Committee on Aviation Environmental Protection (CAEP). Xavier is the ACI representative.

As the Secretary of ACI's World Environment Standing Committee, one of his main tasks is developing, coordinating and implementing policy on all issues relating to the environment and airports.

Noise and gaseous aircraft emissions are the main global issues, but local issues such as air and water quality, energy efficiency and land management also have global significance.

Olav Mosvold Larsen *holds a Cand. Polit degree (MA equivalent) in Political Science from the University in Oslo (UiO). He previously held a position as researcher at the Program for Research and Documentation for a Sustainable Society (ProSus) at UiO, working mainly on issues related to Environmental Policy Integration (EPI) and sustainable production and consumption. Mr Larsen joined Avinor – the Norwegian airport operator and air navigation service provider – in 2007 as senior executive adviser on issues related to sustainable development and transport and climate change.*

Adaptation Versus Mitigation

Discussions on aviation and climate change have been dominated by questions related to mitigation measures. What actions can States and the aviation industry take to reduce emissions from aircraft? What are the roles of aircraft technology, system efficiency, alternative fuels, and market-based measures? All of these issues are directed towards reducing the contribution of aviation emissions to climate change.

In the case of airports, adaptation considerations need to address the changes that must be made to operations and infrastructure in response to changes in the climate and weather patterns. There are two fundamental issues that this discussion needs to address:

- Planning for the continued operation of airports with the changed climate conditions.
- Planning for the continued operation of airports under changed business conditions.

IPCC Expectations

In 2007, the Intergovernmental Panel on Climate Change (IPCC) published its fourth assessment report which included indications of the expected changes in climate over the coming decades and the likelihood of each outcome. Starting with the most likely, the following issues were highlighted: sea level rise considered as virtually certain, temperature increases almost virtually certain, precipitation increases as very likely, and storm activity as likely.

It is important to note that while the above are the expected trends in global average terms, local conditions and changes are expected to vary significantly.

The next four sections look at each of the above issues separately and examine the potential impacts on airports and their operation.

Sea Level Rise

The various numerical models used by the IPCC predict an average sea level rise ranging from 0.2 to 0.5 metres by the year 2100 (based on the medium emissions growth scenario.) Different local effects mean that the actual sea level rises at different airports will vary.

The effects on coastal areas could be significant and could include permanent or regular flooding, storm surge flooding, coastal erosion, and land-subsidence. According to the ICAO airport database there are more than 40 airports on all continents with a recorded elevation above sea level of 3 m (8 ft) or less. There would be many more airports with some of their property lower than this elevation. In many low lying countries such as the Netherlands, the Maldives, and Bangladesh, inundation threatens the entire country rather than just the airports.

This issue poses a major long-term risk to infrastructure located at coastal airports. Runways and taxiways might be unusable at high tide, or even permanently. Terminal buildings, apron areas, access roads and rail links could be impacted. Because the design life of terminal buildings is normally around 50 years, and the design life of runways typically exceeds 100 years, the risks of impacts from climate related events to existing and currently planned infrastructure likely within the next 50 to 100 years need to be assessed.

Possible solutions to minimize these risks are likely to require substantial capital investment: levees and seawalls may be required to prevent flooding, and improved drainage to pump low-lying water from airport areas will be required. Some structures may need to be built higher than current practice. For the lowest and most exposed airports, relocation of the entire airport may need to be considered. Nevertheless, if possible climate change effects are addressed in the planning, design and construction of all new infrastructure projects at airports, the additional costs could be significantly reduced.

Temperature Changes

The IPCC predictions of average temperature increases for the 3rd and 10th decades of the century are shown in Figure 1.

The effects on weather at airports will include decreases in the number of cold days, increases in the number of hot or very hot days, which could, combined with changes in precipitation, have a profound impact on airport operations.

Fluctuations in daily temperature extremes will be higher. Temperature increases will not be uniform and the northern latitudes will experience the greatest rises, resulting in significant impact on winter operations. Other consequences are likely to include changing seasonal demand for passenger and cargo traffic, degradation of local air quality, and melting permafrost under high-latitude airports.

The impacts of temperature changes on airport operations and planning could include such considerations as: aircraft

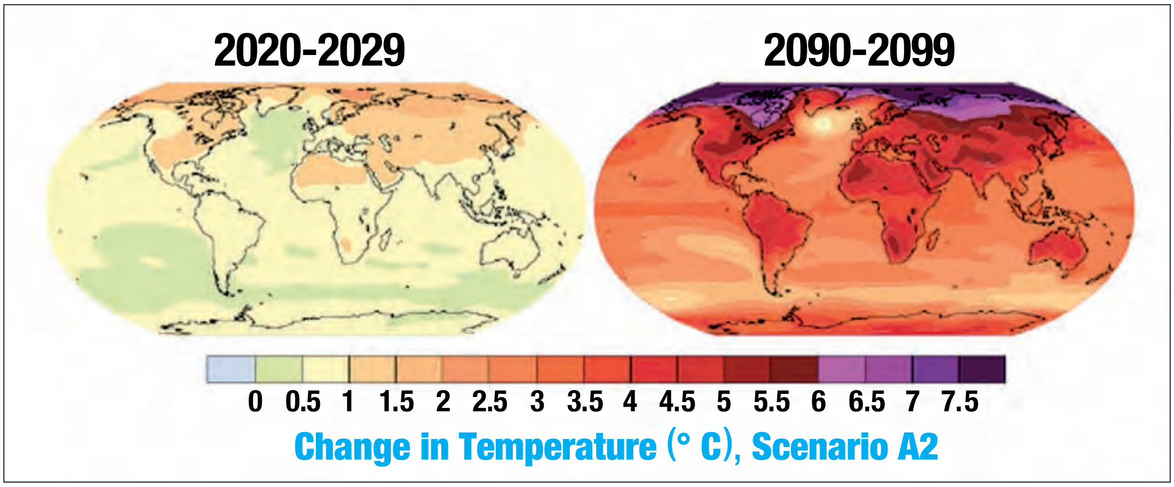


Figure 1: *IPCC Temperature change predictions for the decades 2020-2029 and 2090-2099.*

payload limitations in hot weather, longer runway requirements for long haul flights, slow climb rates that will adversely affect noise levels and airspace usage, diversion of incoming traffic if the temperature is too high, increased demand for cooling of terminals and aircraft, and more stringent local air quality emissions mitigation measures.

Precipitation Changes

The IPCC predicts that precipitation will generally decrease in the tropics and increase in higher latitudes as shown in Figure 2. The climate models also foresee more intense precipitation in many regions.

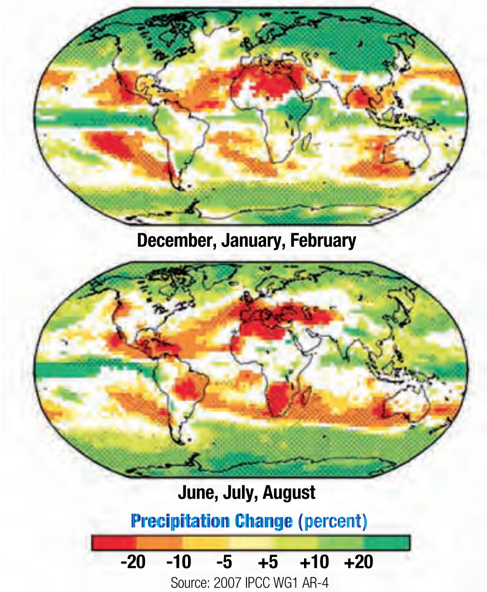


Figure 2: *IPCC worldwide precipitation predictions (2090-2099 relative to 1980-1999).*

These forecast precipitation levels will have profound effects on several regions of the world. For airports, the anticipated effects will include: increased flooding causing runway closures and requirements for improved drainage, water damage causing erosion and landslides, and an increased for storm-water run-off management measures to avoid ground and surface water contamination. In addition, in areas with less precipitation, airports and regions that rely on rainwater for their water supply are expected to experience water shortages and there will be an increase in disruptions from dust storms.

Storm Activity Increases

Storm activity is predicted to increase in both the frequency of events and their intensity. This will be accompanied by increases in wind speed, wave size, and storm surges. The images show storm damage in Norway and measures taken to reinforce coastal defences at airports. Communication equipment, mobile phone masts, RWY and TWY lighting could also be at risk during storms.

Changing Business Conditions

Issues not directly related to weather can also be expected as a result of climate change. For example, business conditions will be impacted by both the actual changes in climate and by efforts to reduce the impacts. Related items that will require risk assessment analysis will include: effects of climate on seasonal passenger demand, effects of climate on the quality and quantity of tourist destinations, cost of additional infrastructure such as sea defences, building stability measures, and increased cooling capacity, potential decrease in airport asset values, shortages of water, power, fuel and land, new storage and delivery infrastructure required for non-drop-in alternative fuels, regulations limiting the growth of aviation, and conducting aviation operations within an aviation emissions cap.

Future Challenges

Clearly, there are substantial challenges that will need to be addressed in the medium and longer terms, including the effects of changing business conditions. It is envisaged that airports will keep their current focus on mitigation, but will also recognize the longevity of airport infrastructure and the need to consider future climate impacts.

In the shorter term, airports should be up-to-date on the latest science on the effects of climate change, and should start the process to better evaluate the risks facing individual airports. Airports should then start addressing some of the uncertainties of climate change outcomes, especially with respect to local effects. This could include planning for new infrastructure with climate change impacts in mind such as considering the criteria for drainage, erosion protection, wind loads for critical infrastructure, and the possible effects on surface access to the airport.

If the predicted changes actually do occur, the possible effects of climate change have the potential to profoundly affect, and possibly devastate, airports and aviation operations in general. All stakeholders need to begin the process by considering the issues involved and assessing the extent of the risks posed.