Newsletter

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Weather-related flight disruptions in a warming world

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There have been numerous causes of air travel disruption since the start of the 21st century. This includes the 9/11 terrorist attacks, eruption of Iceland's Eyjafjallajökull volcano in 2010, and, most recently, the COVID-19 pandemic. While the airline industry has seemingly recovered from the shocks of 2001 (air passenger travel in the US reached its pre-9/11 peak in July 2004 (US Department of Transportation)) and 2010, and still has some way to go with COVID-19, the industry could be dealing with the ongoing effect of climate change impacts for many decades into the future. Our initial analysis, using only publicly available information, is that weather-related flight disruptions at Australia's busiest airports are set to increase in a warming world due, primarily, to an increase in heatwave conditions and thunderstorm activity.

Regular flyers know only too well the inconvenience and frustration of flight delays and cancellations; these can occur for a range of reasons, but most commonly due to extreme weather. Under otherwise normal conditions, Australia has some of the busiest flight routes in the world including Sydney to Melbourne where around a quarter of all flights are delayed, usually due to weather. For Canberra Airport, fog delays are so common that business travellers with morning meetings are advised to arrive the day prior.

A 2010 report commissioned by the US Federal Aviation Administration (FAA) estimated the cost of flight delays in the US at USD32.9B per year (USD4690 per hour, per flight): a cost that is distributed between airlines, passengers, and travel insurance providers (Nextor 2010). Flight delays can increase fuel consumption due to a range of factors including extended taxi times, holding patterns, path stretching, re-routing, increased flight speeds to meet schedules, and proactive measures such as padding schedules in anticipation of delays. This is not only a financial issue, but a reputational problem for an industry facing scrutiny over its CO_2 emissions. Airports also play a crucial role in the global flow of goods and services, making them a key factor of supply chain risk. Due to the interconnected nature of air travel, delays at one airport can propagate across the network making them difficult to anticipate and manage. Given the projected exponential rise in air transport, there is surprisingly little research into how weather-related disruptions will impact this sector in the future.

The key weather phenomena of interest for airport operations are strong winds (particularly crosswinds), fog mist and low cloud ceiling, thunderstorms, heavy rainfall, and extreme heat. Also relevant are tropical cyclones, hail, snowfall, smoke (our latest Black Summer bushfire season illustrated this), dust, humidity and extreme cold. This study seeks to understand the weather events responsible for most delays at Australia's three busiest airports: Sydney, Melbourne and Brisbane, and how this might change in the future under possible climate change scenarios.

Documented airport disruption data are not readily available, however announcements about disruptions are made by major airports on Twitter. For this study, airport Twitter feeds for the last 5 years were mined for information on the occurrence and causes of flight disruptions. This information was then matched against atmospheric data to determine the thresholds at which flight delays and cancellations occurred.

Historical weather and climate information were obtained from the ERA5 reanalysis (C3S 2017) at hourly resolution and validated against in-situ automatic weather station (AWS) observations. Five types of extreme weather events were evaluated: heat, wind speed, fog, rain and thunderstorms. Figure 1 shows Convective Available Potential Energy (CAPE as an indicator of thunderstorm risk)

Figure 1. An example (thunderstorm activity at Sydney airport) of the hourly analysis of weather conditions associated with flight disruptions.

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thresholds for Sydney Airport determined from mining Twitter data. Using the ERA5 reanalysis and thresholds from the 5-year period analysed we were able to develop a 39-year history (1979 to 2018) of the frequency of weather-related disruptions at each of these airports. Figure 2 shows that over this time-period the most frequent weather-related disruptions for Brisbane and Sydney airports were due to fog (54%) and thunderstorm (25%) events, while for Melbourne it was fog (56%) and strong wind (31%) events.

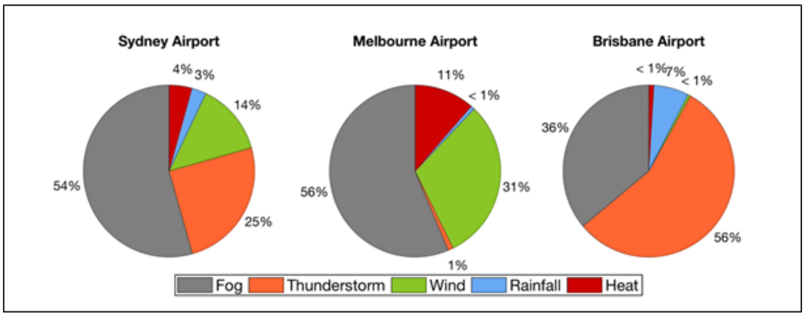

Figure 2. Breakdown of weather-related disruption hours for Brisbane, Melbourne and Sydney airports over the 1979-2018 time period.

Projections of the frequency for each type of weather event have been developed from a seven-member ensemble of global climate model (GCM) projections from the fifth Coupled Model Intercomparison Project (CMIP5). Model output for two of the four Representative Concentration Pathways (RCPs) (formerly 'emission scenarios') was analysed – RCP 4.5 and RCP 8.5. RCP 4.5 is one of two medium stabilisation scenarios and RCP 8.5 represents a very high baseline emission scenario where historical carbon emission trajectories are maintained (van Vuuren et al. 2011).

Figure 3 shows the multi-model ensemble projections for an increase in the frequency of thunderstorm hours at Sydney airport for both RCPs 4.5 and 8.5. Total weather-related disruption hours at Sydney airport, represented as the sum of all weather events (fog, heat, wind, rainfall, and thunderstorms), are set to increase by ~40% under RCP 4.5 (Figure 4), and ~75% under RCP 8.5 (not shown) to 2100. Increases in weather-related disruptions are also expected at Melbourne and Brisbane airports, due primarily to an increase in thunderstorm activity and heatwave conditions.

Allen et al. (2014) used an environments-based approach to suggest an increase in thunderstorm-related delays of 14-30% for Sydney, Brisbane, and Melbourne. However, a wide range of uncertainty exists as very few studies have investigated potential changes. Increasing frequency and intensity of hot days are among the most robust projections from GCM simulations. Recent research indicates summertime daily maximum temperatures in Sydney will regularly exceed 50^{o}C by the end of this century, even under low emission scenarios (Lewis et al. 2019). Extreme heat days historically have not been a major issue for Australian airports, with the hottest summer days typically in the low- to mid-40^{o}C range. However, once maximum temperatures move into the high-40^{o}C range, major issues arise for both ground crews and aeroplanes. Beyond ~48^{o}C tarmac begins to soften, and beyond ~50^{o}C many aircraft cannot take off due to the lower density of hot air, especially when coupled with low humidity.

Fog, from our analysis, has historically been one of the main causes of flight delays. Projections for fog are more uncertain than for temperature, however research from the NSW and ACT Regional Climate Modelling (NARCliM) Project suggests an increase in temperature inversions (when cold air gets trapped beneath warm air) during winter months which will likely cause an increase in fog days for Sydney (Ji et al. 2019). Projections for extreme wind and rainfall events are also more uncertain than temperature projections and show no significant changes from present. However, numerous studies have linked global warming to an increase in the intensity of rainfall events, especially those associated with thunderstorms (Allen et al. 2014), meaning this could also become more problematic in the future.

Flight delays due to bushfire smoke have not been directly considered in this research as historically this has not been a major issue for Australian airports. However, severe bushfire smoke haze during the 2019/20 Black Summer bushfire season caused extensive flight cancellations (see here and here). Given the robust projections for an increase in bushfire weather risk, this is likely to become a significant issue in the future and Risk Frontiers' probabilistic bushfire and grassfire loss model 'FireAUS' could be used to assess changes in this risk.

The projections presented in this study are based on the CMIP5 multi-model ensemble, which was developed almost 10 years ago for the Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5). A new generation of higher-resolution projections are currently being developed as part of CMIP6 and the Coordinated Regional Climate Downscaling Experiment (CORDEX) and both will become available in 2020. These new datasets are expected to greatly improve our ability to produce location-specific climate risk projections due to better model physics and increased spatial resolution. While the high-level message of increasing weather extremes due to increasing temperature is not expected to change, ongoing research will allow us to answer specific questions with more confidence.

Our preliminary research on airport flight disruptions indicates a robust projection for increases in flight delays from weather-related events at Brisbane, Sydney and Melbourne airports under both medium and very high emission scenarios. There is most confidence in the impacts of extreme heat: however, the impacts of other delay-causing events such as thunderstorms, fog, wind and rainfall, are more uncertain. Existing research based on downscaled projections suggests an increase in wintertime fog frequency and the intensity of extreme rainfall events.

Adaptation measures will be necessary to minimise impacts in addition to mitigation (reducing CO_2 emissions). (Note that prior to COVID-19 air traffic had increased substantially in recent decades and was projected to continue increasing at a near exponential

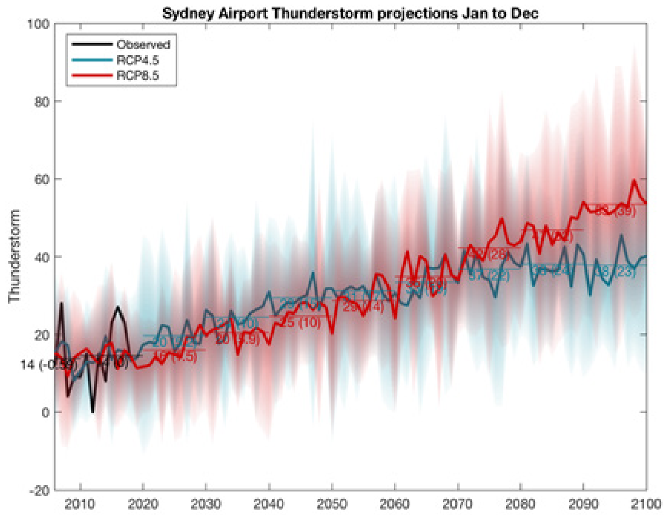

Figure 3. Multi-model ensemble projections for thunderstorm hours at Sydney Airport from 2006 to 2100. Black line represents historical thunderstorm activity determined from the ERA5 reanalysis. The blue and red lines represent RCPs 4.5 and 8.5 projections respectively. Shading indicates two standard deviations from the 7-member ensemble mean. Much of the uncertainty around changes in mean state are associated with natural, year-to-year internal climate system variability.

rate further contributing to emissions.) For example, Melbourne and Perth airports have Category III B rated runways, which allow take-off and landing in fog conditions but are costly to install and maintain. Airlines, passengers and their travel insurance providers will continue to bear most of the costs associated with flight delays.

Australia's vulnerability to weather and climate events was most recently tested during the 2019/20 catastrophic bushfires and drought. The impacts extended beyond the built environment to society more generally and the economy. Organisations need to understand their sensitivities historically and how these may change under future climate scenarios. Recommendations of the Task Force on Climate-related Financial Disclosure (TCFD) are encouraging a science-based risk evaluation and adaptation process, especially for the financial sector. Through ClimateGLOBE, Risk Frontiers is collaborating with Australia's leading climate researchers, and building on decades of catastrophe loss modelling experience, to develop robust assessments of current and projected financial impacts of climate change that are applicable not just to airports, but all organisations.

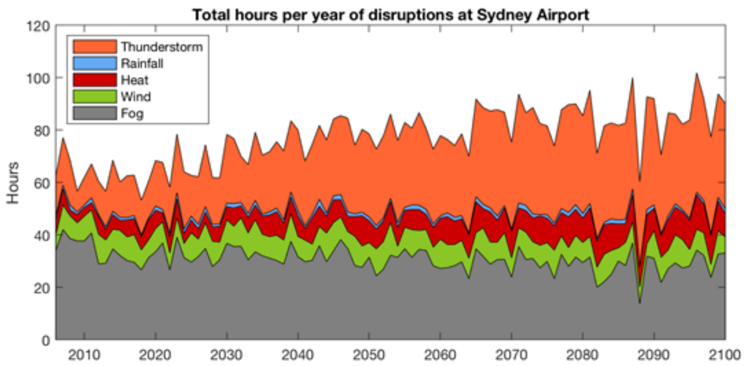

Figure 4. Projections of total weather-related disruption hours at Sydney airport from a 7-member ensemble of GCM simulations under a medium emission (RCP 4.5) scenario. For clarity only the ensemble mean is shown for each type of weather event.

Risk Frontiers' Submission to the Royal Commission into National Natural Disaster Arrangements

The following is the Executive Summary from Risk Frontiers' submission to the Royal Commission into National Natural Disaster Arrangements. Ryan Crompton was a witness at the opening day of public hearings of the Royal Commission on May 25 and his statement can be found here. Risk Frontiers may be called again in later hearings.

The 2019/20 'Black Summer' bushfire season in Australia was extremely damaging. A distinguishing feature of Black Summer was the extended time period over which fires raged throughout several states including New South Wales (NSW), Queensland and Victoria. Our submission focuses on:

- the impacts of Black Summer expressed in terms of numbers of destroyed buildings, insured losses and fatalities;
- how bushfire impacts compare with those arising from other natural perils such as tropical cyclones, floods, hailstorms and earthquakes;
- recommendations for improved bushfire mitigation and resilience, and
- the future of bushfire fighting in Australia.

In terms of bushfire building damage, Black Summer is expected to be comparable to the most damaging seasons (if not the most damaging) in Australia since 1925 after increases in dwelling numbers are taken into account. A point of difference with previous major fire events is the Black Summer damage accumulated throughout the season (or at least first half season) rather than on single days of fire. The Insurance Council of Australia's current estimate of insured losses for Black Summer is $2.23 billion, slightly less than those incurred in the Ash Wednesday (February 1983) fires. Across all perils, bushfires comprise 12% of normalised Australian insured natural hazard losses over the period 1966-2017.

Post-event damage surveys undertaken by Risk Frontiers confirm the significant role that proximity to bushland can play. In the case of the NSW South Coast, approximately 38% of destroyed buildings were situated within 1 metre of surrounding bush. Risk Frontiers observed similar findings in the aftermath of the 2009 Black Saturday bushfires where an estimated 25% of destroyed buildings in Kinglake and Marysville were located physically within the bushland boundary. Land-use planning in bushfire-prone locations needs to acknowledge this risk.

Risk Frontiers is now in a position to characterise the national natural peril profile by comparing risks between perils at a given postcode or comparing the all hazard risk across different postcodes. Postcodes that face the greatest risk of financial loss to insurable assets lie in Western Australia, Queensland or NSW, with flood and tropical cyclone being the most significant perils. Bundaberg has the highest average annual loss relative to all other postcodes. Information like this could be employed to guide national mitigation investment priorities.

We posit the need to adopt an all-hazards, whole of community and nationwide approach to managing large scale disasters. Consideration should be given to multiple large-scale concurrent or sequential events in future disaster planning.

There is a need to encourage community participation and greater private sector engagement. A national bushfire capability development plan should guide investment in the next generation of bushfire fighting capability as we seek to move away from long-standing approaches that are resource intensive and struggle to control fires when conditions are truly catastrophic. This will be important given the trend toward more dangerous conditions in southern Australia and an earlier start to the fire season due at least in part to anthropogenic climate change.

Risk Frontiers Seminar Series 2020

Save the dates and Registration Link

Due to the COVID-19 pandemic Risk Frontiers' Annual Seminar Series for 2020 will be presented as a series of three one-hour webinars across three weeks.

Webinar 1. Thursday 17th September, 2:30-3:30pm
Webinar 2. Thursday 24th September, 2:30-3:30pm
Webinar 3. Thursday 1st October, 2:30-3:30pm

Risk Modelling and Management Reloaded

Natural hazards such as floods, bushfires, tropical cyclones, thunderstorms (including hail) and drought are often thought of, and treated as, independent events despite knowledge of this not being the case. Understanding the risk posed by these hazards and their relationship with atmospheric variability is of great importance in preparing for extreme events today and in the future under a changing climate. Risk Frontiers' ongoing research and development is focussed on incorporating this understanding into risk modelling and management as we view this as the way of the future. We look forward to sharing some of our work during our 2020 Seminar Series.

Presentation Day 1

- Introduction to Risk Frontiers Seminar Series 2020
- Historical analysis of Australian compound disasters – Andrew Gissing

Presentation Day 2

- Climate conditions preceding the 2019/20 compound event season – Dr Stuart Browning
- Black Summer learnings and Risk Frontiers' Submission to the Royal Commission into National Natural Disaster Arrangements – Dr James O'Brien, Lucinda Coates, Andrew Gissing, Dr Ryan Crompton

Presentation Day 3

- Introduction to Risk Frontiers' 'ClimateGLOBE' physical climate risk framework
- Incorporating climate change scenarios into catastrophe loss models – Dr Mingzhu Wang, Dr Tom Mortlock, Dr Ryan Springall, Dr Ryan Crompton

It is with sadness we herald the retirement of Prof John McAneney from the position of Managing Director of Risk Frontiers and thank him for his valuable contribution over the last 18 years. It is with pleasure we announce that Dr Ryan Crompton has been promoted to Managing Director as from 1st July 2020.

John took over the leadership of Risk Frontiers from Prof Russell Blong in 2003. Under John's stewardship, both inside Macquarie University and more recently outside as a private company, Risk Frontiers has grown to be an internationally recognised risk management, modelling and resilience organisation. John has nurtured the professionals who have chosen to work at Risk Frontiers and promoted the culture of tremendous work ethic, intellectual curiosity and scientific rigour underpinning the company. Our new Managing Director, Dr Ryan Crompton, looks forward to doing the same.

Announcing his retirement to Risk Frontiers staff John commented:

Being in charge of Risk Frontiers has truly been the best part of my working career. It has been a privilege to have been able to work closely with so many brilliant people and help create a research capability that is second to none in our field. Few are given that privilege and I'm grateful to Russell for entrusting me with that responsibility so many moons ago. I'm also indebted to each of you for your support and I look forward to catching up again when next in Australia.

John has agreed to remain on the Board as a Non-Executive Director until at least 31 December 2020.

In rising to the role of Managing Director, Dr Ryan Crompton brings his long academic achievements and commercial experience with Risk Frontiers since 2003. Ryan was appointed to Risk Frontiers while studying at Macquarie University soon after John joined, and has since held numerous roles within the company, most recently as Acting Managing Director. He has developed strong relationships with staff, clients and associates over many years and we look forward to his leadership of the Risk Frontiers team.

We look forward to your continued support of Risk Frontiers.

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