

Aeolian Dust as a Transport Hazard

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35 **Abstract**

36 The effects of blowing dust on transport operations are often mentioned as one of the
37 significant impacts of aeolian processes on human welfare. However, few studies
38 have been presented to demonstrate this impact. This research examined official air
39 traffic incident reports in Australia for inclusively 1969-2010 to characterize the
40 hazard of blowing dust to aviation in the country, the first such study of its kind. For
41 the 42 year record, 61 incidents were identified (mean 1.4 per annum), with the large
42 majority occurring in the first half of the 1970s. Only 20% of incidents occurred from
43 1984 onwards. Australian dust activity has not decreased over time, and the reduction
44 in incidents is partly explained by improvements in aviation technology. The
45 centralisation of Air Traffic Control operations to major coastal cities may however
46 have reduced pilot reporting of dust-induced aviation incidents. By type of dust
47 activity, dust storms were associated with nearly half of the reported incidents and
48 dust hazes produced around a quarter. Only 5% of incidents resulted in any physical
49 damage to aircraft and only one case involving personal injury was reported. The
50 majority of the adverse effects on aviation due to dust (nearly 60% of reported
51 incidents) were related to difficulties for navigation and completion of scheduled
52 journey. Since aircraft damage and bodily harm were rare, the impact of dust in
53 Australia is mostly that of inconvenience and associated raised economic costs. From
54 1990, the temporal pattern of incidents does not show any significant increase despite
55 several intensely dusty years associated with recent droughts. This suggests that
56 Australian aviation safety may be relatively resistant to the adverse effects of
57 atmospheric dust as a hazard.

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59

60 **Keywords:** duststorm; sandstorm; air safety; aerosols; visibility; eolian

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69 **1. Introduction**

70 When the wide ranging impacts of aeolian dust are discussed, the effect of suspended
71 dust as a hazard for transport operations is commonly cited (e.g. Goudie, 2009; Okin
72 et al., 2011). By reducing visibility, impairing mechanical function and even
73 interfering with communication systems, dust has considerable potential to cause
74 economic and strategic cost by disrupting the conveyance of both people and goods
75 (Goudie and Middleton, 1992; Walker et al., 2009). The negative effect of these
76 impacts is one of the well recognised ‘off-site’ costs associated with wind erosion and
77 dust raising (Piper, 1989; Pimental et al., 1995; Williams and Young, 1999). Apart
78 from a purely economic cost, transport accidents caused by blowing sand or dust
79 storm events can also result in injury and death.

80

81 Despite the frequent mention of dust representing either a hazard, imposition or
82 disrupter to different forms of travel, there appear to be relatively few studies that
83 have reported relevant data or presented case examples. Information relating to road
84 traffic incidents caused by dust seems to be the most common (e.g., Buritt and Hyers,
85 1981). Pauley et al. (1996), for instance, described the details a major accident in the
86 San Joaquin Valley of California in 1991, where blowing fields adjacent to an
87 interstate highway led to 164 vehicles colliding and 168 dead or injured. In the Lower
88 Mojave Valley of California, Laity (2003) examined an area of locally enhanced
89 aeolian activity, the blowing dust from which had caused fatalities on highways in the
90 valley. Novlan et al. (2007) state that between one and two road traffic fatalities occur
91 on average annually in the El Paso, Texas region due to dust storms. Nationwide for
92 the United States, Ashley and Black (2008) included analysis of dust storms in their
93 assessment of the deadliness of nonconvective wind events. Between 1980 and 2005
94 they report that 62 deaths were related to dust storms affecting road vehicles.

95

96 As well as disruption to road transport, air transport is also affected by dust. Airport
97 closures and flight cancellations have been reported globally for locations within
98 major mineral aerosol pathways such as the Canary Islands (Criado and Dorta, 2003),
99 Riyadh, Saudi Arabia (Maghrabi et al., 2011), Abu Dhabi, UAE (de Villiers and van
100 Heerden, 2007) and Sydney, Australia (Leys et al., 2011). For the latter, the intense
101 dust storm activity of 23rd September 2009 that affected much of eastern Australia
102 resulted in delays, which caused seven flights to break the 11 p.m. curfew for night

103 operations in place at Sydney Airport (DIT, 2009). From other airline industry
104 sources, Williams and Young (1999) estimated the costs of a 1994 diverted Boeing
105 747 landing at Melbourne instead of Adelaide due to a South Australia dust event as
106 up to AUD 80,000. Elsewhere, Miller et al. (2006) have highlighted the significant
107 effects of dust on military air operations in deserts. They detail the case of Operation
108 Iraqi Freedom, and the support that dust-monitoring from satellite sensors provided
109 operations from aircraft carriers in the southwest Asia theatre (also Walker et al.,
110 2009). The operational problems encountered in the 1980 U.S. hostage rescue attempt
111 in Iran, during which blowing dust dogged air operations and caused a collision
112 between a helicopter and fixed-wing aircraft, were also linked to haboob events
113 (Miller et al., 2008).

114

115 With a considerable portion of its area lying in semi-arid or arid climatic conditions,
116 and with often large-scale dust raising events a common occurrence (McTainsh et al.,
117 2005; Strong et al., 2010; Leys et al., 2011), transport operations in Australia are
118 strongly subject to hampering by dust. The existence of population centres in or on
119 the margin of dust yielding areas, the large distances between settlements and the
120 prevalence of light aircraft for servicing remote stations, especially in the drier centre,
121 ensures aviation operations are especially vulnerable to dust in Australia. The long
122 distance transport of sediment during major dust events also means that aerosols
123 suspended into the atmosphere can affect Australian airspace well away from source
124 areas (Bowler, 1976; Sprigg, 1982; McGowan and Clark, 2008a). Here, we analyse
125 official air traffic incident records to characterise the nature of aeolian dust as a
126 hazard to air transport across Australia for 1969-2010.

127

128 **2. Methods**

129 *2.1 Data sources*

130 The Australian Transport Safety Bureau (ATSB) is the Federal government agency
131 with the remit to investigate and catalogue air safety issues for the Commonwealth. A
132 search of all air incident records held by the ATSB was conducted to extract those
133 officially catalogued incident occurrences that included either the terms “dust”,
134 “sand” or “willy willy” within the description of the incident. Sand was selected to
135 identify those dust events possibly described by aviation staff as sandstorms. Willy
136 willy is the Australian name for dust devil or dust whirl. This term was initially used

137 as a search trigger because it was also anticipated that such meteorological
138 phenomena could likely feature air traffic incidents involving dust raising. The search
139 process was helped by the fact that those incidents in which wind-raised dust or sand
140 was a dominant factor typically came under the ATSB event type classifier
141 “Environmental-Weather-Other”. Each event report contained a suite of standard
142 information such as date, location, aircraft model and manufacturer, plus a text
143 summary of the known incident details. The degree of information included in reports
144 was typically of relatively good detail and provided considerable data to assist in the
145 interpretation of each incident.

146

147 Careful inspection of the returned records ensured that the final list for analysis
148 contained only those incidents with a mention of aeolian dust as a causative factor in
149 some way. This check eliminated cases where dust was reported only as a
150 consequence of the incident (e.g. reports mentioning dust and gravel kicked up by an
151 aircraft overshooting a runway), or, where the dust involved was of volcanic origin.
152 From this quality control of the data, it was seen that none of the incidents identified
153 by willy willy occurrence contained any explicit mention of dust being present.
154 Rather, all willy willies were related to adverse effects of turbulence and wind-shear
155 on aircraft operation, not the effects of aeolian entrainment or suspension of sediment.
156 As a result, the willy willy reports were not included in the final analysis of the data.

157

158 To aid assessment of the dust-related air incidents, the incident reports were
159 interpreted alongside the Dust Event Database (DEDDB) held at Griffith University.
160 The DEDDB is a temporally extensive inventory (> 1960) of daily dust activity
161 throughout Australia and is based on weather codes and data collected by the Bureau
162 of Meteorology.

163

164 In using the ATSB dataset to assess the impact of dust on aviation, there is one
165 important caveat. In September 2009, large portions of eastern Australia experienced
166 severe dust storms (Leys et al., 2011). This period of highly intense dust activity had a
167 major impact on air travel, from flight groundings to airport closures, but no official
168 reports of dust-related incidents were returned from the ATSB at all for this period. A
169 follow-up data extraction and inspection of all ATSB records (regardless of specific
170 dust mention) for the most intensely dust affected week of 19-26th September verified

171 that none of the reports could be attributed to dust. The lack of incidents for this
172 period highlights that the ATSB record relates strictly to dust as a hazard to active
173 flights, and does not reflect the full impact of dust on air operations, such as delays or
174 cancellations.

175

176 *2.2 Classification of incidents*

177 After those records related to blowing dust had been gathered, the incident
178 description, the officially classified incident type, as well as damage and injury
179 information was analysed to allocate each incident into different groups for summary
180 results. The type of dust activity associated with incidents was also determined.

181 Descriptions of the dust event within the air report were augmented by reference to
182 the DEDB to classify the nature of aeolian activity for each incident. DEDB records
183 enabled a nationwide assessment of the extent, intensity and duration of dust activity
184 for those days when air incidents occurred.

185

186 **3. Results and Discussion**

187 *3.1 Type of adverse effect*

188 During the period 1969 to 2010 inclusively for Australia, a total of 61 officially
189 reported air incidents were found to be attributable in some way to the effect of blown
190 dust. (A further nine incidents were attributable to the impact of willy willies, but as
191 stated, these are not included in the subsequent analysis.) Relatively few of the cases
192 reported any damage being caused to aircraft or equipment (4.9%) and only a single
193 incident resulted in physical harm to personnel, whereupon the reported level of
194 injury was rated as slight (Table 1).

195

196 >> TABLE 1

197

198 The dominant impact caused by dust on Australian aviation through the study period
199 relates to adverse effects on navigation. Incidents that involved a return to the initial
200 take off location (16.4%), diversion to and landing at some alternative to the original
201 destination (27.9%), pilot reported uncertainty of position (8.2%) or an inability to
202 even locate the final destination (4.9%) were all related to enhanced difficulties in
203 navigation due to atmospheric dust (57.4% overall). Occasionally, dust was reported
204 specifically as preventing flight Visual Meteorological Conditions (VMC) from being

205 maintained. The breakdown of such conditions, where flight is guided by visual
206 contact with the ground and the avoidance of other aircraft is through visual sighting,
207 all necessitated some kind of deviation from the originally intended route or
208 destination in order to maintain VMC.

209

210 For 9.8% of all incidents, a reduction in communications performance due to the
211 presence of dust was the primary issue prompting the report. Dust storms are known
212 to create static and atmospheric attenuation of signals, which can interfere with radio
213 communications (e.g., Edwards and Brock, 1945; Goudie and Middleton, 1992). The
214 degradation of communications was also occasionally mentioned in some incidents
215 where a different adverse effect took precedence in the classification. For example,
216 where radio problems were cited in conjunction with positional uncertainty. In total,
217 communication difficulties attributed to dust were mentioned across 13.1% of all
218 incidents.

219

220 While the impact of decreased visibility was implicit in many of the adverse effects
221 (e.g. the failure to locate an intended destination from the air), the impact of reduced
222 visibility was stated as the primary effect of dust in 23.0% of the incidents. Frequently
223 these cases involved flight activities in visibilities that contravened Australian flying
224 regulations and thereby triggered an incident report. The 'Miscellaneous' category in
225 Table 1 contains those incidents (4.9%) where dust affected flying operations in a
226 manner that could not be conveniently classified into the other categories, for
227 example, dust-related effects on aircraft handling.

228

229 A notable aspect of the reports is that 13.1% featured some mention of inadequate
230 weather forecasting playing a part in the incident. Predominantly, these mentions
231 were criticisms of pre-flight forecasts not predicting the presence of dust en route, and
232 its eventual presence causing the flight to be altered in some way. By law in Australia,
233 an official pre-flight forecast which indicates that visibility is likely to be reduced
234 below certain specified values due to the likely presence of dust, either en route or
235 affecting the destination, requires pilots to carry extra fuel before departure. Correct
236 forecasting of dust therefore is an important requirement for successful, efficient air
237 passage, and erroneous or inaccurate forecasts can prompt interruptions to operations
238 such as fuel-forced diversions or returns to aerodrome of origin.

239

240 *3.2 Types of aeolian activity*

241 Of the 61 incidents identified, 47.5% were related to the effects of dust storms (Table
242 2). The events placed into this group were those where reports contained sufficient
243 information on the nature of the dust (e.g. pilot or air traffic control description),
244 together with cross checking of the DEDB, to infer that the incident was related to
245 conditions of active dust raising. An air incident in the context of a large dust storm
246 event is shown in Figure 1. Instances of dust haze, where the suspended sediment had
247 been uplifted by a previously occurring dust storm, or was located far removed from
248 sources of emission, accounted for 23.0% of incidents. A further 8.2% of the reports
249 mentioned dust associated with the occurrence of thunderstorms. Events in this
250 category were determined from the incident report descriptions only. Dust raised by
251 thunderstorm downdraughts can often be relatively local in extent, thus if such an
252 event affects a flight, it may well go undetected by any observer site and therefore not
253 feature in the DEDB. Relatively few of the reports (6.6%) were interpreted as being
254 cases involving local, small-scale instances of aeolian entrainment. Such small-scale
255 instances of blowing activity were associated only with aircraft operations on the
256 ground, for example on dirt runways (Table 2). For the final 14.8% of reports,
257 confident classification of the aeolian activity responsible for the incident was not
258 possible from either the report information or DEDB resources.

259

260 >>TABLE 2

261

262 >>FIGURE 1

263

264 *3.3 Phase of flight and type of air operation affected*

265 Table 2 also reveals that the large majority (68.9%) of dust-related air incidents
266 occurred during the ‘in flight’ phase of aircraft operation. Given that the greatest part
267 of any journey is the portion spent in flight, and this involves change in location by
268 the aircraft over time, cruising is the phase where the potential for encountering dusty
269 conditions is greatest. While pre-flight weather forecasting attempts to reduce the
270 level of hazard for this flight phase, the changeable atmospheric conditions of dust
271 events makes the cruising phase especially susceptible to those adverse effects
272 grouped as navigation-related (e.g., forced returns, positional uncertainty).

273

274 While accidents resulting in damage were rare overall, their highest frequency was
275 during the takeoff phase, where both a dust storm and local entrainment were
276 associated with incidents serious enough to damage machinery (Table 2). On the final
277 approach and descent into the final destination, diversions can be required or
278 positional uncertainty develop at this late stage of the flight. Such problems can arise
279 during descent due to a worsening of visibility and flying conditions when the altitude
280 decrease during landing brings the aircraft into higher concentrations of dust nearer
281 the surface. Dust ceilings during major dust storms are commonly <2500 m. For
282 instance, McGowan and Clark (2008b) estimated the ceiling for one western
283 Queensland dust event to be 1000 m, while in a very large dust storm in 2002, the
284 ceiling was estimated from aircraft to be 1500-2500 m (McTainsh et al., 2005).
285 During the landing phase itself, only 4.9% of incidents occurred, all of which were
286 related to impairments of visibility.

287

288 Both the role of the aircraft and the transport operation it was conducting are also
289 included within the official ATSB incident reports. This information allowed
290 assessment of which type of conveyance dust represented the biggest hazard. Table 3
291 shows that fixed-wing aircraft were by far the main form of aircraft affected, not
292 surprising given their dominance of flight operations. Only two incidents involved
293 helicopters, but one of these resulted in one of the relatively few instances of serious
294 damage. Table 3 also reveals that passenger transport was the main form of operation
295 affected by dust. All the incidents where damage was reported (three events, Table 1)
296 were associated with charter operations.

297

298 >>TABLE 3

299

300 *3.4 Spatial distribution of incidents*

301 Mapping incident locations reveals the majority occurred in and around the Lake Eyre
302 Basin (LEB) (Figure 2), the main dust emitting region on the continent (Prospero et
303 al., 2002; Bullard et al., 2008; Strong et al., 2010). The regional city airports at
304 Broken Hill, Mount Isa and Alice Springs are on the fringe of the LEB, lying in
305 known pathways from the basin (e.g., Sprigg, 1982), and were all associated with
306 multiple dust-related incidents (Figure 2). The flight route between Mount Isa and

307 Alice Springs was also particularly subject to interruption by dust. Four reports were
308 located at or near Mildura, which is located both within the main southwest pathway
309 of dust from the LEB as well as within a local, predominantly agricultural dust source
310 region, the Mallee (McTainsh et al., 1990). A small cluster of incidents was also
311 found in southern Western Australia, a secondary dust source region of Australia
312 (McTainsh and Pitblado, 1987).

313

314 >> FIGURE 2

315

316 The number of events seen at coastal or humid tropical northern locations (>500 mm
317 rainfall, Figure 2) is of some interest because these incidents occurred well away from
318 the dominant dust source areas. These incidents mainly involved either small scale,
319 localised dust raising, which was typically restricted to the aerodrome or immediate
320 area of incident, or conversely, were related to very large scale events involving the
321 advection of dust along pathways to the continental margins and beyond. A total of 14
322 (around a quarter) of incidents occurred outside the dry zone of the 500 mm isohyet.
323 Three of these involved highly point sourced local entrainment events, two were
324 associated with major dust storms breaking out of the dry interior and four were due
325 to hazes experienced in coastal areas. As an example of the latter, the DEDB
326 identified that there was significant wind erosion occurring in western Queensland on
327 both the 1st and 2nd January 1970 with dust raising reported around Charleville and
328 Longreach. A day later, much of the entrained dust had been transported to the east
329 along the south-east dust path (McTainsh, 1998) and had formed the reported dust
330 haze that rendered the destination Heron Island undetectable for one flight (Figure 2;
331 Table 2).

332

333 *3.4 Temporal distribution of incidents*

334 Figure 3 shows that the vast majority of reported incidents were from the earliest part
335 of the record, with 54.1% in the first half of the 1970s. After this peak, incidents
336 became fewer in number but showed a relatively consistent frequency up until 1983.
337 Much fewer cases have been reported in the last 20 years of the record. Given the
338 complexity of the factors that determine the number of dust-related incident reports
339 arising for any given year, any correlation between frequency of incident reports and
340 measures of annual dust activity would not be expected to be particularly strong.

341 Despite this, it is still informative to examine the time series of incidents next to a
342 record of annual dustiness.

343

344 The Dust Storm Index (DSI) is a metric that has been successfully used to express
345 long term (>50 years) trends in dust activity for Australia (for a detailed review see
346 O’Loingsigh et al., submitted). The DSI value for a location is derived from the daily
347 records of dust weather codes reported annually at that observer station, with variable
348 weightings for the different dust codes (e.g. local dust events are weighted less than
349 severe dust storms) in the form:

$$DSI = \sum_{i=1}^n [(5 \times SDS) + MDS + (0.05 \times LDE)]$$

350
351 where *DSI* is annual Dust Storm Index from *n* stations and *i* is the *i*th value of *n*
352 stations for *i* = 1 to *n*. The number of stations (*n*) is the total number of stations
353 recording a dust event observation in the year. *SDS* is Severe Dust Storm (maximum
354 daily dust code: 33, 34, 35), *MDS* is Moderate Dust Storm (maximum daily dust
355 codes: 30, 31, 32 and 98), *LDE* is Local Dust Event (maximum daily dust codes: 07,
356 08 and 09). The development and explanation of the DSI is beyond the scope of this
357 paper, and is fully explained by McTainsh and Tews (2007). For this study, a national
358 annual DSI value was calculated from 180 (*n*) long term measuring locations
359 throughout Australia. The DSI is used here to provide a general context of nationwide
360 dustiness with which to interpret the annual variability of air incidents (Figure 3).

361

362 >>FIGURE 3

363

364 Variability in rainfall is a characteristic of the Australian climate, and droughts are
365 well known to enhance both the frequency and magnitude of dust emission on the
366 continent (McTainsh et al., 1989; McTainsh et al., 2005). While there were small
367 increases in the frequency of air incidents for dry years showing relative dust peaks in
368 1983 and 1994, the major annual peaks of dustiness were 2002 and 2009 (DSI = 2.68
369 and 3.17, respectively). The beginning of the 21st century was associated with a
370 period of prolonged drier conditions referred to as the Millennium Drought that
371 severely affected eastern Australia. Significantly, however, the Millennium Drought
372 and the attendant increase in wind erosion did not have any increased impact on

373 aviation (Figure 3). It seems therefore that contemporary air transport in Australia, at
374 least in terms of officially catalogued reports, is little affected by periods of enhanced
375 dust activity.

376

377 It is interesting to note that although the 1970s was the period of time when dust-
378 related incidents were most common, there were no aircraft reports for the years
379 1974-75. Pronounced La Niña conditions held sway over Australia in 1974, which
380 made it a very wet year in which dust activity was significantly suppressed (Figure 3).
381 Moomba for instance (location in Figure 2) had an annual rainfall in 1974 of 869 mm,
382 an amount around four times its long term average. Inundation by floodwaters,
383 growth of surface-protecting vegetation in response to the rains and residual soil
384 moisture levels persisting throughout the country's dryland regions meant 1975 was a
385 reduced dust year too, and no incident reports were catalogued for that year either.

386

387 After 1983 the number of reports lessened considerably with only 20% of the events
388 occurring in the latter 27 years of the study. Through this period however, a general
389 increase in aerosol levels was observed between 1997-2007 for Australia (Mitchell et
390 al., 2010), and the DSI also shows an overall upward trend for this period (Figure 3).
391 The decrease in reports of dust-associated air incidents cannot therefore be attributed
392 to any significant reduction in dust activity throughout the continent. Furthermore,
393 there has been no consistent decrease in air travel, which could be another possible
394 explanation for the reduced number of dust-related reports over time (Figure 4).

395

396 >>FIGURE 4

397

398 As there is no evidence of decreased dustiness concurrent with the reduction in
399 number of air incident reports, one possible explanation is that advancements in
400 technology have helped reduce the impact of dust on aviation. For instance, the
401 increasing prevalence of Global Positioning System (GPS) units in aircraft from the
402 early 1990s has significantly reduced positional uncertainty in conditions of reduced
403 visibility. Also, improved communications due to the progressive replacement of
404 High Frequency (HF) radio by the introduction of now almost universal Very High
405 Frequency (VHF) radio coverage for air traffic control purposes renders
406 communication much less susceptible to degradation due to static in dust storm

407 conditions. As evidence, the last instance of a report citing communication difficulties
408 from dust was May 1979.

409

410 Reduced reporting by pilots may also be a possible explanation for the reduced
411 number of reports through the study period. In the early years covered by the study,
412 areas of regional Australia that were outside the coverage of Air Traffic Control radar
413 were served by regional reporting stations known as “Flight Service Units” (FSU).
414 These were, in effect, radio stations manned by local airport Flight Service Officers
415 with whom pilots filed flight plans and passed position progress reports via HF or
416 VHF radio. Whilst the procedures were not mandatory, the extant culture was such
417 that the significant majority of pilots used the service. These units were dis-
418 established progressively from the early 1980s and effectively disappeared within
419 about 10 years. Whilst centralised Air Traffic Control took on procedural control for
420 instrument flights, a culture developed where pilots flying in visual conditions rarely
421 used the new service. Hence, many of the track deviations and diversions that
422 occurred outside of controlled airspace were not apparent to air traffic controllers and
423 hence were less likely to be reported by pilots. It is possible therefore that much of the
424 reduction in aviation incidents attributable to dust is more apparent than real.

425

426 **4. Conclusion**

427 Between 1969 and 2010 inclusively for Australia, there was a total of 61 (and an
428 annual average of 1.4) officially reported air incidents where blowing dust was
429 identified as a factor. The vast majority of these reports occurred in the early 1970s,
430 but two very wet years in this period (1974 and 1975) saw no incidents. Across all
431 incidents there were no fatalities and very few occurrences of injury or damage-
432 causing accidents attributable to atmospheric dust. The fact that almost three quarters
433 of the incidents resulted in navigational or visibility-based problems means dust
434 impacts upon aviation can be described largely in terms of economic cost and
435 inconvenience.

436

437 An attempt to fully quantify the economic cost of navigational difficulties caused by
438 dust would need consequences such as flight diversions to be valued, and these
439 assessments would be hard to perform. From their study in South Australia, Williams
440 and Young (1999) valued the detour of a single large passenger jet in 1994, but found

441 the general opinion of private aviators was that blowing dust was not responsible for
442 significant increases in flying costs, based on the 20 years before 1999. Many other
443 aspects of increased expense, such as the greater maintenance costs necessary for
444 aircraft operating in commonly dusty environments are also not taken into account in
445 this study. Furthermore, the data used here relate to the reported impact of dust on
446 active flights, thereby representing the active hazard that dust represents. The data
447 therefore cannot be used to assess major financial costs for air transport which result
448 from dust activity such as flight cancellations and re-scheduling.

449

450 One issue obfuscating the drawing of air safety conclusions from the ATSB record is
451 the known change in incident reporting protocol following the demise of Flight
452 Service Units in Australia. While it seems highly probable that technological
453 advancements have helped reduce the frequency of dust-related navigational and
454 communication incidents, the extent to which the decline in reports over time reflects
455 a changing degree of the dust hazard, or reflects reduced reporting of dust-induced
456 aviation incidents by pilots, is uncertain. Despite this uncertainty, it is clear that the
457 reduced frequency of incidents cannot be accounted for simply by an overall decrease
458 in atmospheric dust loading. While there has been an upward trend in dustiness, the
459 number of air incidents has not increased. Furthermore, from around 1990, periods of
460 highly elevated dustiness (typically associated with drought periods) have not seen
461 jumps in the number of safety incidents, especially in terms of damage or injury. This
462 leads to the inference that contemporary Australian aviation safety demonstrates
463 considerable resistance to the hazard of blowing dust.

464

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619 Table 1: Nature of the adverse effect to aviation caused by dust

620

Broad category of effect	Specific disruption	% of incidents (n)
Navigation (57.4%)	<i>Diversion</i> : scheduled trip could not be completed and diversion to unplanned landing was required	27.9 (17)
	<i>Return</i> : aircraft required to return to its take-off location	16.4 (10)
	<i>Destination</i> : unable to locate intended destination	4.9 (3)
	<i>Position</i> : reported uncertainty in aircraft location	8.2 (5)
Communication (9.8%)	Communications reported as impaired	9.8 (6)
Damage (4.9%)	Resulted in aircraft damage	3.3 (2)
	Resulted in aircraft damage & injury	1.6 (1)
Visibility (23.0%)	Impairment of visibility was the primary reported effect of dust	23.0 (14)
Miscellaneous (4.9%)	Report of miscellaneous, non-optimal flying operations caused by dust	4.9 (3)

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623 Table 2: Adverse effect of dust to aviation by type of dust activity and the phase of
 624 flight impacted
 625

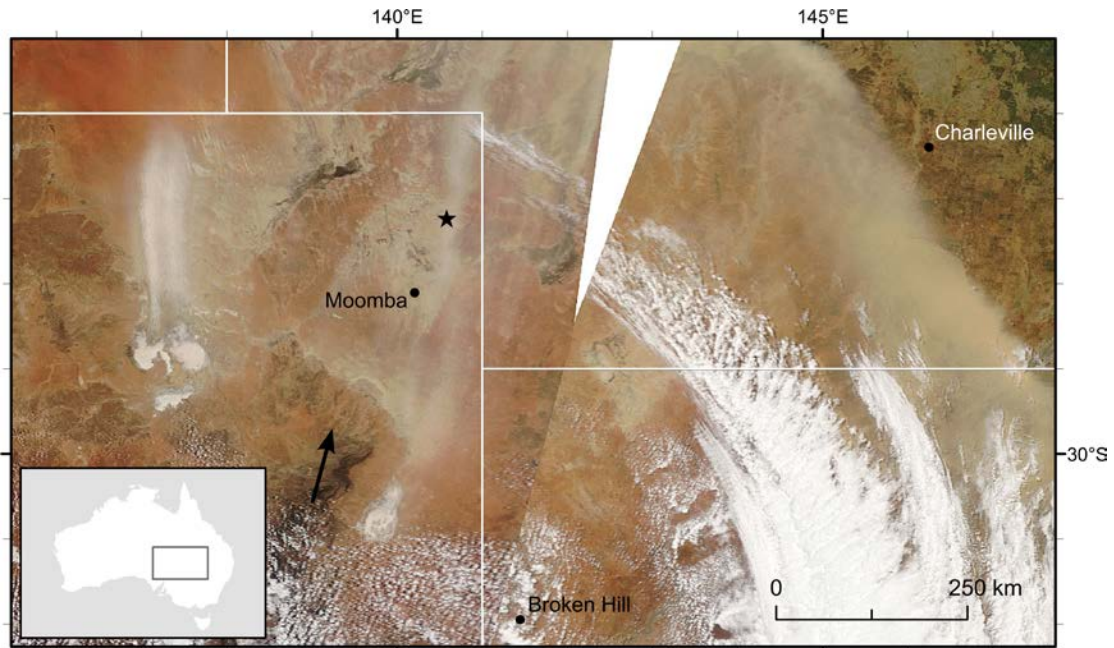
Phase of flight	Adverse effect	Type of dust activity					Total
		Dust storm	Haze	Thunderstorm related	Local entrainment	Undetermined	
Taxiing or takeoff (14.8%)	Damage	1			1		2
	Diversion	1					1
	Visibility	1	1		2		4
	Miscellaneous		1		1		2
In flight (68.9%)	Damage					1	1
	Diversion	9	2	1			12
	Position		3	1			4
	Destination		3				3
	Return	5	1	1		3	10
	Visibility	4				2	6
	Communications		1	2		3	6
Approach or descent (11.5%)	Diversion	4					4
	Position		1				1
	Visibility	1					1
	Miscellaneous	1					1
Landing (4.9%)	Visibility	2	1				3
		29 (47.5%)	14 (23.0%)	5 (8.2%)	4 (6.6%)	9 (14.8%)	

626
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629 Table 3: Dust-related incidents by type of aircraft involved and nature of air operation
 630

Type of aircraft		% (n)
Fixed wing		96.7 (59)
Helicopter		3.3 (2)
Type of air operation		
Passenger	Charter	46.0 (28)
	Low capacity	1.6 (1)
	High capacity	42.6 (26)
Freight		1.6 (1)
Unknown		8.2 (5)

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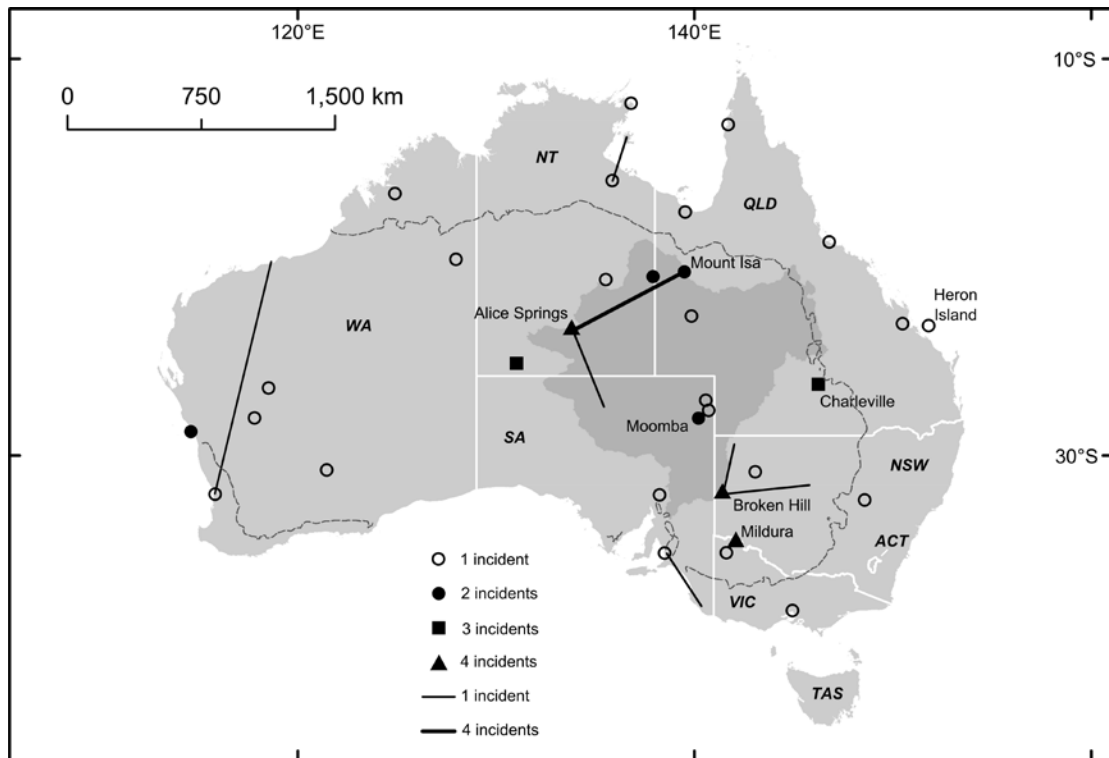


633

634 Figure 1: ‘True colour’ Moderate Resolution Imaging Spectroradiometer (MODIS)
 635 imagery showing wide scale dust storm conditions and location (star) of the incident
 636 reported at 10:30 CSuT, 2nd February 2005. With insufficient fuel for diversion, the
 637 small aircraft was forced to emergency land due to decreasing visibility in the dust
 638 storm. Arrow marks general wind direction. Satellite image was captured 1 hour 30
 639 minutes after time of the incident report. More detailed remote sensing analysis of this
 640 dust event is available in Baddock et al. (2009). Image source: NASA MODIS

641 Rapidfire.

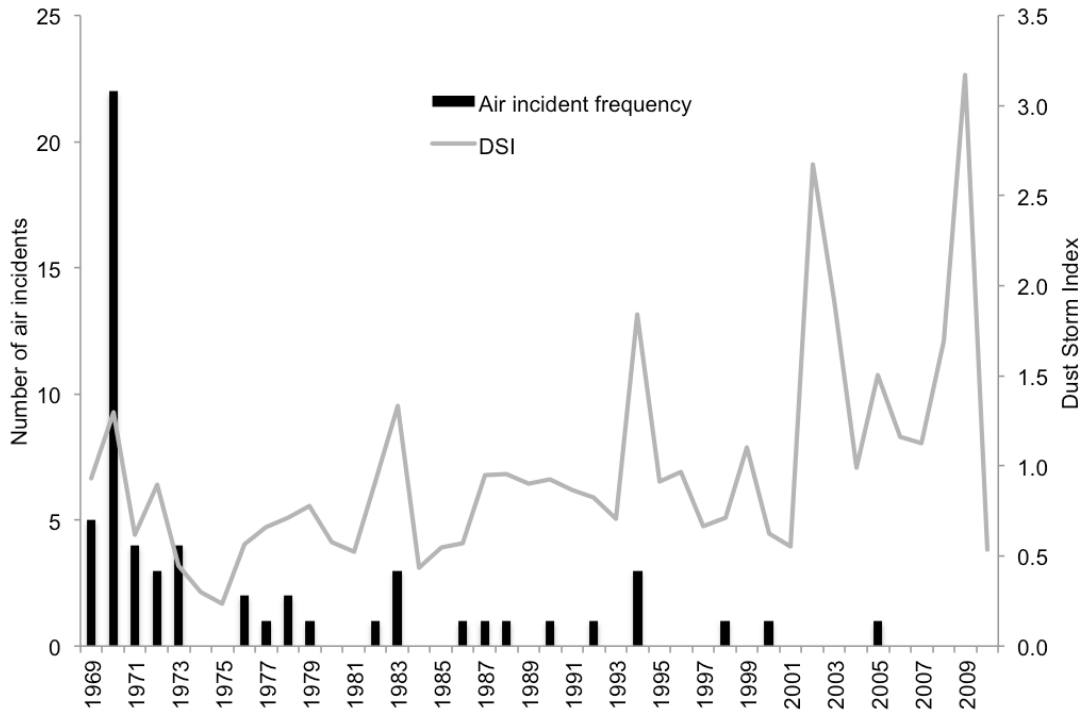
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644 Figure 2: Spatial distribution of reported incidents (two incidents not included due to
 645 insufficient location information). Points represent either a specific location when
 646 provided in the report, or, the named location where a report mentioned the incident
 647 occurring within a certain area. Lines represent routes when the best spatial
 648 information for an incident was along a flight path. Lake Eyre Basin extent is
 649 indicated in darker grey. Dashed line is 500 mm isohyet.

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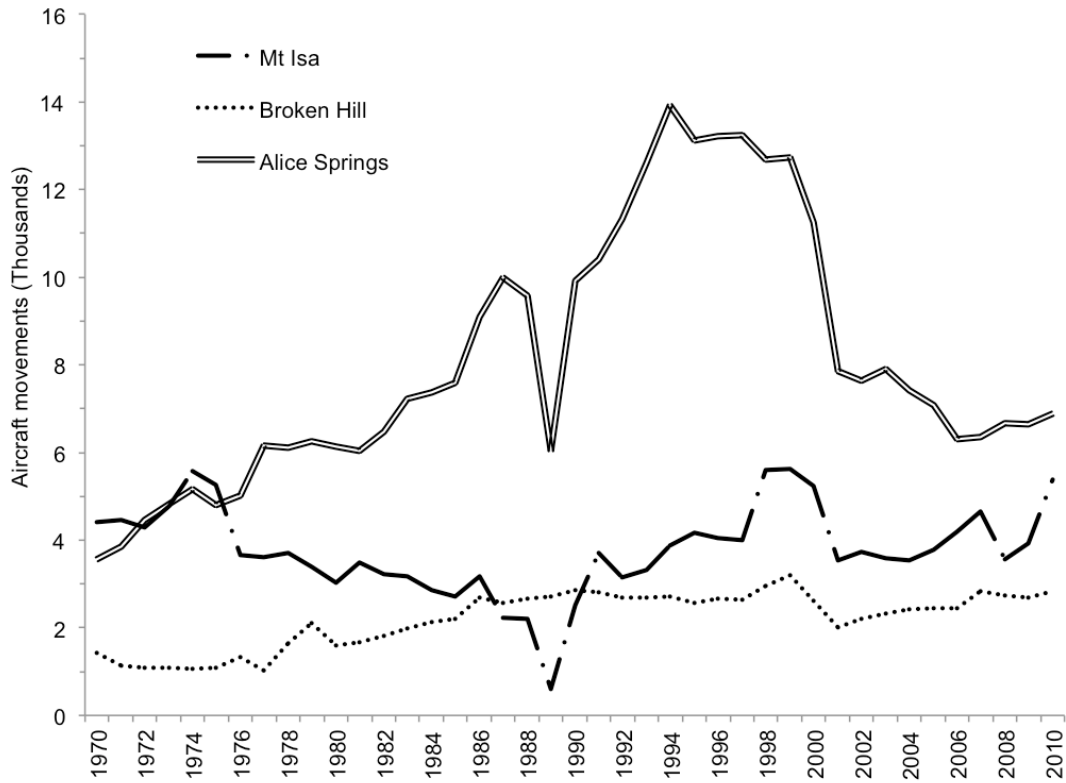


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652 Figure 3: Annual Dust Storm Index (DSI) and frequency of aviation incident reports.

653 See explanation of DSI in the text.

654



656

657 Figure 4: Annual aircraft movements for three regional Australian airports bordering
 658 the Lake Eyre Basin (locations in Figure 2). Movements are inbound and outbound
 659 flights, and relate to regular public transport schedules only. Data are for financial
 660 years, and official accompanying notes state that for Mount Isa the apparent decline
 661 1987-90 is due to non-reporting by an airline for this period. Data from BITRE
 662 (2011).

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