J 3.3 A THUNDERSTORM AND LIGHTNING ALERT SERVICE FOR AIRPORT OPERATIONS

Rodney J Potts
Centre for Australian Weather and Climate Research
Bureau of Meteorology, Melbourne, Australia

1. INTRODUCTION

Thunderstorms and the associated weather have a range of impacts on operations at airports that include disruption to air traffic and to ground operations. Lightning in particular presents a hazard to ground staff and various ground operations will cease while thunderstorms and associated lightning are in the area. The disruption to ground operations compounds the disruption to air traffic when there are thunderstorms in the terminal area. The flow-on disruption can last for many hours and extend around the country as aircraft cannot be unloaded and refuelled, they cannot leave parking bays and arriving aircraft may have no place to park. The pressure to maintain operations at airports is great and there has been a need for better real time information about thunderstorms and associated lightning in the terminal area that enables better strategic and tactical planning of ground operations by the airlines without compromising safety requirements.

To satisfy this requirement an Automated Thunderstorm Alert Service (ATSAS) has been developed by the Bureau of Meteorology and implemented at the major airports around the country. Systems that support the ATSAS integrate radar information and lightning data and automatically generate end-user graphical and text products that show the location and movement of thunderstorm cells and the presence of lightning near the airport. The products are updated frequently and can be more easily understood by airline personnel. The airlines in conjunction with airport authorities have developed response procedures that enable them to better manage the disruption and minimize impacts.

* *Corresponding author address:* Rodney Potts, Centre for Australian Weather and Climate Research, Bureau of Meteorology, Melbourne VIC Australia, 3000; email: r.potts@bom.gov.au

In this paper we briefly describe the systems that support the ATSAS, present a case study and discuss operational experiences and impacts.

2. THE AUTOMATED THUNDERSTORM ALERT SERVICE (ATSAS)

The systems that support the ATSAS have been described elsewhere (Potts et al 2007) and we present only a brief description here.

In recent years there has been work in the Bureau of Meteorology to develop a Nowcast Applications Server (NAS) (Bannister 2007) that integrates several radar data processing applications including the Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) application (Dixon and Wiener 1993). The NAS processes radar data for major locations around the country and the processed information, including TITAN data, are then made available to display systems and other 'downstream' applications that generate 'end-user' products.

At locations where the ATSAS service is provided single station Vaisala TSS928 lightning sensors have been installed and these detect cloud-to-ground (CG) and cloud (IC) lightning that occurs nearby based on electrostatic, magnetic and optical lightning signatures. The CG lightning strikes that occur within approximately 30 NM are grouped into 'flashes', assigned to range and azimuth sectors and summed over an 'aging interval' of 10 minutes. The nominal range for detection of cloud lightning is 10 NM and the number of cloud flashes is also summed over the 'aging interval'. The sensor provides reports of detected CG and IC 'flashes' that are updated each minute. The reported detection efficiency for CG strikes within 10 NM is 90% and experience has shown this decreases with range and the associated current.

An application known as ATIFS takes TITAN storm track data from the NAS and lightning data from the TSS928 lightning sensor and automatically generates the graphical

ATSAS products at 1-minute intervals. The end-user graphical products include a plan view of the Airport locality that shows the location of thunderstorm cells and the forecast movement out to 30 minutes. Lightning data from the TSS928 lightning sensor is also shown assigned to range and azimuth sectors. The graphical products are updated each minute and made available on a registered user internet web page that the airlines can access. A 'heads-up' text alert is generated by the ATIFS application when storm cells first occur within 30 NM or any lightning flashes are reported and this is sent via SMS to end users.

Recognizing that different users have different requirements and procedures the aim with the ATSAS has been to provide a product which has the highest possible integrity using available data and which enables users to make decisions about ramp operations in accord with their own requirements. There are uncertainties with the ATSAS products and there are ongoing efforts to address these. Experience has also shown that end-users often require supporting and consistent evidence from different sources before critical operational decisions are made and there is a need to present relevant information in a way that can be easily understood by the users. In this context the development of the ATSAS has benefited from ongoing consultation with industry representatives to ensure user requirements are met to the extent possible and users understand the uncertainties and limitations.

The airlines have developed joint working arrangements for coordinating ramp shut-downs which will be initiated by operational staff within the airlines based on the ATSAS products. The shutdown will occur when there is a risk of CG lightning within 5 NM of the airport. The thresholds for initiating the shutdown are fairly conservative and these are still being refined.

The ATSAS is now operational at Cairns, Brisbane, Coolangatta, Sydney, Melbourne, Adelaide, Perth and Darwin airports.

3. GPATS lightning network

A commercial lightning detection network is operated in Australia by Global Position and Tracking Systems Pty. Ltd (GPATS) (http://www.gpats.com.au/). The network comprises Lightning Position and Tracking System (LPATS) sensors that use time of arrival technology to identify and locate CG lightning strikes. Commercial arrangements associated with this network currently limit the ability to display the GPATS lightning data in real-time products for end users. Also the spatial distribution of the sensors for this network is such that the detection efficiency and location accuracy is suitable for the ATSAS requirements only in southeast parts of the country. Nevertheless these data are valuable for validating the ATSAS products. Also the GPATS network is progressively being upgraded so the detection efficiency and location accuracy in remaining parts of the country will gradually improve.

4. CASE STUDY – Sydney Airport, 31 Jan 2008

On 31 Jan 2008 thunderstorms developed southwest of Sydney and moved over the Airport and Figures 1a, 1c and 1e show a sequence of ATSAS products at 0651, 0721 and 0921 UTC respectively. The products show the radar identified storm cells that moved across the airport with the cells colour coded according to the VIL and forecast positions to 30 minutes. The numbers of CG lightning flashes reported by the TSS sensor for the previous 10 minutes are displayed in each range / azimuth sector as the storms approach. The number of cloud flashes is also displayed.

In a post analysis the ATSAS products were compared to the radar data and CG lightning 'strikes' detected by the GPATS network for the 10 minute period corresponding to the TSS data (Figures 1b, 1d and 1f). These show lightning strikes (marked with an 'X') as well as the total number of 'strikes' detected by the GPATS network for sectors corresponding to the TSS928 data. In processing the GPATS data we have followed Biagi et al (2006) and assumed positive polarity strikes with an estimated peak current less than 15 kA are misclassified cloud strikes and they have been ignored.

Comparison of the figures shows general consistency between the identified storm cells in the ATSAS product, the radar echoes and the lightning data. However there are some differences with the lightning data in particular and further work is required to better understand these and to improve the integrity of the ATSAS product.

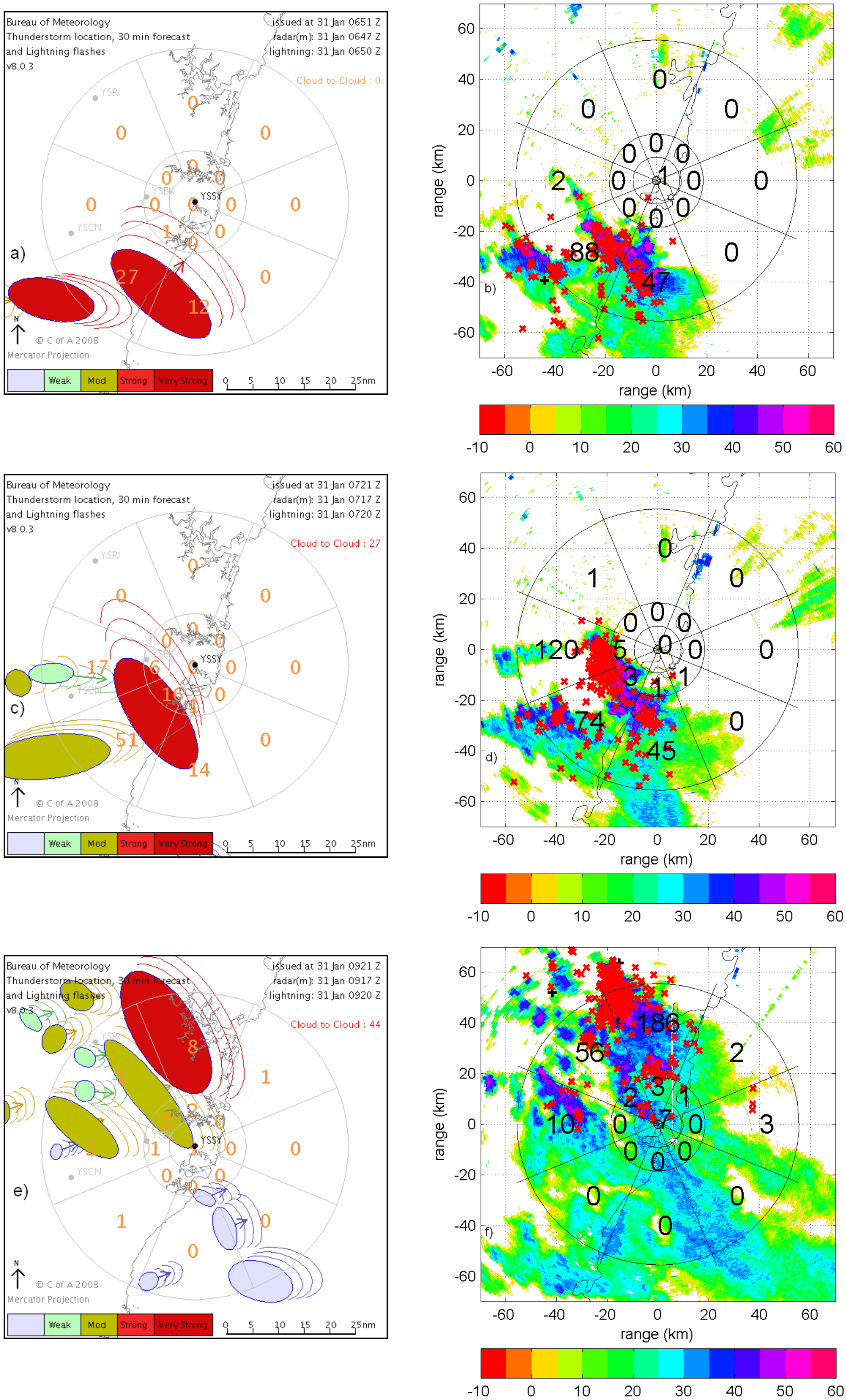

Figure 1. Sequence of ATSAS products for Sydney Airport for 31 Jan 2008 at (a) 0651, (c) 0721 and (e) 0921 UTC. Corresponding radar images overlayed with CG lightning strikes detected by the GPATS network over a 10 minute period are shown at (b), (d) and (f) (see text). The color bar shows the radar reflectivity in dBZ. The range rings are at 5, 10 and 30 NM.

There are instances in Figure 1 when the TSS sensor or the GPATS network reports a flash or strike in a given sector which is not reported by the other. These can be partly explained by the fact that lightning flashes reported by the TSS sensor may include multiple CG 'strikes' which are separated by several kilometers but there are uncertainties with both systems. Experience has shown that the detection efficiency for the TSS sensor decreases substantially with range for lightning further than 10 NM from the sensor so the flash density reported by the TSS at longer ranges is much less than what is reported by the GPATS network. Because the TSS sensor is a single point sensor that relies on a waveform analysis to determine the range for a lightning strike there are some uncertainties in the calculated range. The detection efficiency of the GPATS network and accuracy in locating lightning strikes is also not well known.

As previously indicated the TSS sensor incorporates an optical sensor which enables the detection of cloud lightning and Fig 2 shows the time history of the count for IC lightning compared with the CG lightning in the 5-10NM range and CG lightning within 5 NM. Previous studies have shown that cloud lightning often

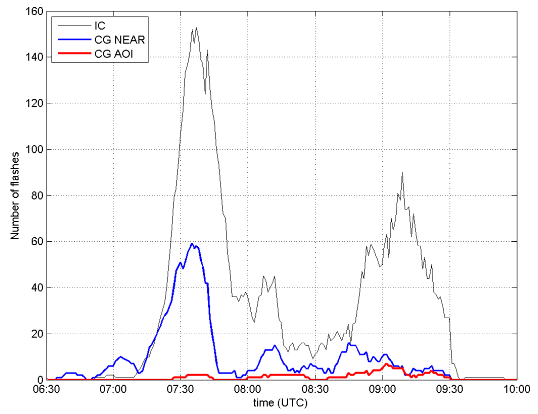

Figure 2. Time historyof lightning flashes detected by TSS928 sensor for IC, CG at 5-10 NM and CG within 5 NM.

precedes CG strikes (MacGorman et al 2006, Patrick and Demetriades 2006) and the relationship between increases in the IC lightning and the occurrence of CG lightning within 5 NM of the sensor is of interest. For this case the flash rate for IC lightning increased sharply from 0711 UTC with the first CG flash within 5 NM reported at 0727 UTC.

For this event the airlines were anticipating a probable ramp closure based on the ATSAS products and advice to evacuate the ramp was given at 0722 UTC. The ramp area was closed for the period 0725 – 0934 UTC, a period of 129 minutes. It should be noted the TSS sensor reported CG flashes within 5 NM for the period 0727 – 0930 UTC. The known impacts resulting from the ramp closure and the disruption to air traffic associated with the passage of the storms across the terminal area included 17 cancellations, 9 diversions, 60 flights delayed for periods to 3 hours and one emergency landing due to fuel limitations.

5. OPERATIONAL IMPACTS

Table 1 shows a summary of ATSAS events for the 12 month period 1 May 2007 – 30 Apr 2008 at airports where the ATSAS was operational and the ramp was closed, noting that Adelaide and Coolangatta became operational on 16 Oct 2007. This shows 83 events when ramp operations ceased with a total shutdown time of 2770 minutes or 46 h 10 min. The frequency distribution for the duration of the

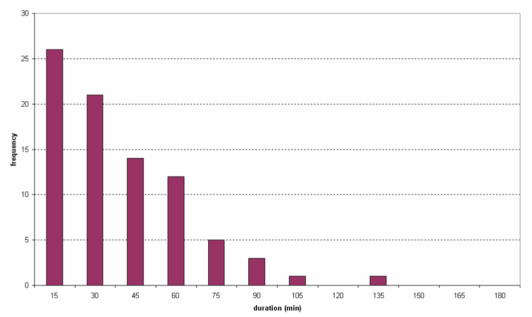

Figure 3. Frequency distribution for duration of ramp shutdown 1 May 2007 – 30 Apr 2008.

shutdown (Fig 3) shows most events are less than 15 minutes with around 90% of events less than 60 minutes duration.

The impacts shown in Table 1 relate to only one airline and present brief comments on delays, cancellations and diversions. For some events the impacts are unknown and where relevant this is indicated. In regard to the delays, cancellations and diversions it is difficult to separate and quantify those that result from ramp closures and those that result from the disruption to approaching air traffic but the details presented provide a measure of the impacts. Moreover, both contribute to loss of efficiency in the management of air traffic.

As previously indicated the flow-on impacts of a ramp shutdown can be significant. To illustrate, the ATSAS event at Sydney Airport on 9 Dec 2007 when the ramp was closed for 53 minutes resulted in an accrued delay of 2440 minutes for operations across Australia for a single airline. Thus the flow-on impact of a shutdown can be a significant multiple of the duration for which the ramp was actually closed.

6. DISCUSSION

Ramp closures will cause delays due to an inability to load or unload passengers or baggage or an inability to service the aircraft (fuel, catering, cleaning). Cancellations may also occur due to factors such as consolidation of delayed flights, crew duty hours exceeding limits, curfew limits at the destination. It should also be noted that the presence of thunderstorms in the terminal area can lead to delays or diversions for approaching aircraft and this will compound the disruption caused by ramp closures. These delays, cancellations and diversions mean that aircraft may not be available for subsequent flight sectors for which it is scheduled. The resultant disruption to airline operations and to the efficiency of managing air traffic can extend around the country and last many hours.

The ATSAS service is now operational at Cairns, Brisbane, Coolangatta, Sydney, Melbourne, Adelaide, Perth and Darwin Airports and experience has demonstrated its utility. The radar data and lightning data are complementary and integration of these data in the ATSAS product gives end users increased confidence in the integrity of the product and enables more effective use of the information. The products are updated frequently and can be more easily understood by airline personnel. Airlines have developed coordinated response procedures to better manage the disruption and minimise the impact to operations.

A number of uncertainties and limitations remain with the ATSAS products. There are uncertainties with the TSS lightning data and integration of the GPATS lightning data into the ATSAS product should improve the integrity of the end product. In most cases storms develop and move across an airport from some distance away and already have associated lightning as they approach and for these cases the GPATS data complements the TSS data.

Storms can also develop rapidly and this may occur overhead with little or no warning before CG lightning occurs. For high based storms the radar reflectivity may be low making the detection and tracking of such storm cells problematic. Lightning can also occur with residual anvil cloud or stratiform cloud and distinct storm cells may not be identified in the radar data. As indicated earlier cloud lightning generally precedes the occurrence of CG lightning and the utility of total lightning systems for provision of warnings for public safety has been demonstrated (MacGorman et al 2006, Patrick and Demetriades 2006).

7. CONCLUSIONS

In this paper we describe the integrated use of radar data and lightning data to provide automated real-time warnings for thunderstorms and associated lightning for airport ground operations. The ATSAS service is currently operational at Cairns, Brisbane, Coolangatta, Sydney, Melbourne, Adelaide, Perth and Darwin airports and experience has demonstrated its utility.

8. ACKNOWLEDGEMENTS

Information on the impacts of the thunderstorm events and associated ramp closures due to lightning was provided by John Crane and Graham Rennie and this is acknowledged.

9. REFERENCES

Bally, J., 2004: The Thunderstorm Interactive Forecast System: Turning automated thunderstorm tracks into severe weather warnings. Weather and Forecasting, 19, 64-72.

Bannister, A.J., J. Bally, K. Cheong, S. Dance, T. D. Keenan, and P. J. Purdam, 2007: The Australian Nowcasting System. Preprints 33rd International Conference in Radar Meteorology, American Meteorological Society.

Biagi, C.J., K.L. Cummins, K.E. Kehoe and E.P. Krider, 2006: NLDN performance in Southern Arizona, Texas and Oklahoma in 2003-2004. 19th Intl. Lightning Detection Conference, Vaisala Inc. Tucson, AZ, CD-ROM.

Dixon, M., and G. Weiner, 1993: TITAN: Thunderstorm Identification, Tracking, Analysis and Nowcasting – A radar based methodology. J.Atmos.Oceanic Technol., 10, 785-797.

MacGorman, D., I. Apostolakopoulos, A. Nierow, J. Cramer, N. Demetriades and P. Krehbiel, 2006: Improved timeliness of thunderstorm detection from mapping a larger fraction of lightning flashes. 1st International Lightning Meteorology Conference. Vaisala Inc., Tucson, AZ, CD-ROM.

Patrick, G.R. and N.W.S. Demetriades, 2006: Using LDAR II total lightning data in an operational setting: Experiences at WFO Fort Worth TX. 1st International Lightning Meteorology Conference. Vaisala Inc., Tucson, AZ, CD-ROM.

Potts, R., 2005: The application of TITAN for thunderstorm nowcast operations. Hollis A.J. (ed) *Hydrological Applications of Weather and Climate Modelling: Extended Abstracts from the Seventeenth BMRC Modelling Workshop*, BMRC Research Report No 111, 2005.

Potts, R.J., J.Bally and T.Williams, 2007: An automated thunderstorm alert service for airport operations. Preprints 33rd International Conference in Radar Meteorology, American Meteorological Society.

Table 1. Ramp shutdown events for period 1 May 2007 – 30 Apr 2008. (Note Adelaide and Coolangatta became operational on 16 Oct 2007.)

PORT	Date	Duration of shutdown (min)	Ramp shutdown (UTC)	Impacts
Adelaide (YPAD)	6/12/07	45	0620-0705	Not known
	21/12/07	45	0010-0055	Not known
	2 events	**90**		
Brisbane (YBBN)	22/09/07	15	0647-0702	None known
	7/10/07	45	0835-0920	Extensive delays on numerous acft.
	8/10/07	55	0805-0900	7 flights delayed for periods of 30 to 90 minutes
	9/07/07	45	0710-0755	15 flights delayed for periods of 30 to 60 minutes
	10/10/07	65	2305-0010	3 flights delayed for periods of 30 to 90 minutes. 2 cancellations
	10/10/07	30	0955-1025	5 delays from 30 to 60 mins
	26/10/07	31	1355-1326	Not known
	28/10/07	15	1005-1020	Not known
	5/12/07	22	0453-0515	Some delays
	6/01/08	50	0335-0425	Some delays
	6/01/08	10	0437-0447	34 flights delayed by an average 60 mins. Impacts compounded due to earlier closure.
	6/02/08	43	0522-0605	A few direct cancellations
	6/02/08	15	0615-0630	A few cancellations
	6/02/08	10	0809-0819	Disruption compounded by earlier ramp closure plus ramp closure in Sydney.
	28/03/08	25	0455-0520	Not known
	28/03/08	20	0608-0628	Not known
	16 events	**496**		

Cairns (YBCS)	12/10/07	10	0555-0605	One flight delayed 14 mins.
	12/10/07	10	0619-0629	Nil
	4/12/07	10	0403-0413	Nil
	11/01/08	11	0914-0925	Nil
	11/01/08	37	0933-1010	30 min delay 1 flight
	12/01/08	50	0920-1010	None known
	14/01/08	50	0920-1010	Minor delays
	7/02/08	16	0258-0314	Nil. No aircraft ops.
	7/02/08	53	0442-0535	Nil. No aircraft ops.
	7/02/08	20	0620-0640	Nil. No aircraft ops.
	14/02/08	93	0955-1127	1 aircraft delayed
	11 events	**360**		
Coolangatta (YBCG)	5/12/07	82	0208-0330	Numerous delays, diversions and cancellations
	26/10/07	30	0540-0610	Not known
	26/10/07	40	0955-1035	Not known
	6/01/08	17	0445-0502	None reported
	6/02/08	36	0540-0616	A few cancellations
	6/02/08	11	0632-0643	A few cancellations
	6/02/08	36	0656-0732	A few cancellations
	26/03/08	12	0708-0720	Not known
	26/03/08	46	0740-0826	Not known
	14/04/08	40	0310-0350	Not known
	14/04/08	20	0910-0930	Not known
	18/04/08	14	0228-0242	Diversion to YBBN
	12 events	**384**		
Melbourne (YMML)	3/05/07	19	2059-2118	Not known
	3/05/07	16	0423-0439	One acft delayed 20 mins
	1/11/07	45	0320-0405	29 delays of between 30 to 60 mins
	3/12/07	9	0305-0314	Nil
	3/12/07	10	0330-0340	Nil
	3/12/07	5	0352-0357	Nil
	20/12/07	10	0510-0520	Not known
	20/12/07	10	0545-0555	Not known
	20/12/07	45	0610-0655	Not known
	4/02/08	59	0509-0608	Severe disruptions to schedule
	10 events	**228**		
Sydney (YSSY)	7/06/07	18	2102-2120	Major impact
	7/06/07	27	2132-2159	Major impact
	7/06/07	10	2224-2234	Major impact
	9/07/07	20	2125-2145	Not known
	9/07/07	12	2226-2238	None known
	9/07/07	15	2306-2321	Not known
	14/09/07	30	0455-0525	7 departure delays from 30 to 60 minutes
	12/10/07	15	0110-0125	Four flights delayed for up to 30mins
	12/10/07	17	0305-0322	Flights delayed for up to 35 mins
	26/10/07	65	0445-0550	Not known

	2/11/07	15	2355-0010	Not known
	3/12/07	48	0302-0350	Numerous delays and cancellations
	3/12/07	10	0414-0424	Numerous delays and cancellations
	3/12/07	29	0659-0728	Numerous delays and cancellations
	4/12/07	15	0702-0717	Some delays
	7/12/07	53	0507-0600	Eight cancellations and numerous long delays
	9/12/07	53	0420-0513	6 flights cancelled. Numerous delays outbound.
	16/12/07	25	0530-0555	Numerous inbound flights delayed by approx 30 mins
	13/01/08	20	0525-0545	None reported
	20/01/08	78	0612-0730	Significant delays of 30 mins or more for 30 flights
	31/01/08	129	0725-0934	Many cancellations and diversions.
	6/02/08	73	0809-0922	Affected every city pair operating both in & out of YSSY & all sectors down line. 2 flights were denied taxi clearance prior to YSSY curfew
	7/02/08	77	0112-0229	Two flights cancelled and quite a few delays
	26/02/08	65	0650-0755	Many delays, plus quite a few cancellations and/or diversions
	26/02/08	12	0908-0920	Minimal, but compounded problems caused by earlier storm
	27/02/08	56	0754-0850	2 flights cancelled and delays on average of around 60 minutes.
	28/02/08	46	2348-0034	Several aircraft held on ground. A few pair cancellations
	7/03/08	43	0845-1028	Not known
	7/03/08	15	1035-1050	Not known
	29/03/08	23	0655-0718	Not known
	13/04/08	70	0235-0345	Delays
	13/04/08	28	0855-0923	Major delays/cancellations
	32 events	**1212**		
TOTAL	**83 events**	**2770**		