MAUSAM, **56**, 1 (January 2005), 83-88

551.5 : 629.13 : 551.501 : 551.46.072(267.37).

Episodes of aircraft icing during ARMEX phase-I

R. P. SHIVHARE

Air HQ (Vayu Bhawan), New Delhi – 110 011, India

e mail : rpshivhare@yahoo.com

सार – विमानन के समक्ष आने वाली बड़ी मौसम आपदाओं में से एक उड़ान के मध्य हिमन (इनफलाइट आइसिंग) है। आरमेक्स चरण– I के दौरान अरब सागर के ऊपर से उड़ान भरते हुए रूस द्वारा निर्मित ट्रांसपोर्ट वायुयान ए.एन.–32, की बीस उड़ानों में से तीन अवसर ऐसे थे जब यान का सामना उड़ान के मध्य हिमन से हुआ। प्रबल सिनॉप्टिक स्थितियों और सवंहनी मेघ की तुलना करते हुए हिमन की घटनाओं का अध्ययन किया गया। इससे यह ज्ञात हुआ है कि वायुयान यथोचित क्षैतिजीय पवन अपरूपण के साथ संबद्ध संवहनी सेल्स के आस–पास उड़ान भर रहा था। उड़ान की उँचाई के स्तर पर तापमान –6 से –8 डिग्री सेलसियस के बीच पाया गया था। जल की अत्यंत ठंडी बूँदों की भारी मात्रा में विद्यमानता सक्रिय और तीव्र संवहन के साथ संबद्ध समझी जा सकती है जो प्रायः मानसून की सक्रिय स्थितियों में पाई जाती है।

ABSTRACT. In-flight icing is one of the major weather hazards to aviation. During ARMEX Phase-I, there were three occasions out of twenty sorties when in-flight icing was encountered while flying over Arabian Sea in the Russian made transport aircraft AN-32. The icing episodes were studied *vis-à-vis* the prevailing synoptic situations and the convective cloud features. It was found that the aircraft was flying in the vicinity of convective cells associated with considerable horizontal wind shear. The temperature at the flight level was observed to vary from -6 to -8° C. The presence of large amount of supercooled water droplets can be assumed to be associated with the active and intense convection that is usually found under the active monsoon conditions.

Key words – ARMEX, Intensive observation period, Aircraft icing, Flight data recorder, Meteosat, Meso-scale, Radio sonde, GPS.

1. Introduction

The Arabian Sea Monsoon Experiment (ARMEX) Phase-I was conducted during SW monsoon of 2002 under the sponsorship of the Deptt. of Science and Technology. The IAF participated by carrying out airborne weather observation sorties during intensive observation period declared by the ARMEX Study Group.

An aircraft while cruising in sub zero temperature encounters the icing. It is classified into rime, clear (glaze) and mixed, based on its formation and appearance. The intensity of Icing is reported as trace, light, moderate and severe (Terry, 2001). The accumulation of ice on the exposed surface of an aircraft mainly causes structural stresses resulting into malfunctioning of controls and changes in the aerodynamic characteristics of the aircraft.

2. Data and methodology

As and when the aircraft experienced the icing, the de-icing equipments were switched on as a flight safety measure. The wind and temperature data were recorded. The track of the aircraft and its position where icing was encountered, photograph of the radar console, satellite picture of nearest full hour UTC, and evidence photograph of icing taken at that time; were also recorded and studied. During the ARMEX period, three episodes of icing were recorded. The details of the episodes are listed below in Table 1.

3. Result of case study

3.1 *Case - I : 18 June 2002*

Synoptic features – On 18 June 2002, monsoon had covered most parts of central Arabian sea, Konkan & Goa, parts of Madhya Maharashtra, most parts of Marathwada and some parts of Telengana. The off-shore trough was extending from north Gujarat coast to Kerala coast. Intense convection prevailed between 13° N to 17° N, 67° E to 74° E. West coast stations had received moderate to heavy precipitation indicating that monsoon was active in the Arabian sea.

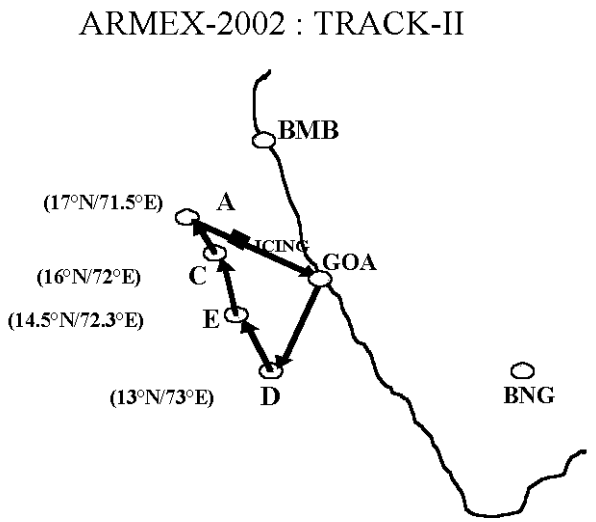

Fig. 1. Track of the aircraft & the position of icing

PHOTOGRAPH OF ICING ON COCKPIT WINDOW
Date/Time : 18 Jun 2002/1313 IST Altitude : 20000 Feet
Location: BETWEEN POINT A AND GOA (16.24/72.27)

Fig. 2. Icing on the wiper of the front screen of the aircraft

TABLE 1

Episodes of the aircraft (A/C) icing

S. No.	Date	Time (IST)	Altitude in feet	Co-ordinates	Location	Prevailing weather conditions
1.	18 Jun 2002	1259 to 1317 (18 m)	17,000' (5100m) to 20,000' (6000m)	17°00' N, 71°00' E to 16°15' N, 72°38' E	Between point 'A' (17° N / 71.5° E) to Goa. Approximately 300 km from Goa	Overcast sky. Scattered convective cells extending beyond 20,000 feet. Off shore trough extending from north Gujarat to Kerala
2.	26 Jun 2002	1259 to 1302 (03 m)	20,000' (6000m)	16°46' N, 71°58' E to 16°58' N, 71°58' E	Between point 'A' (17° N / 71.5° E) to Goa. Approximately 300 km from Goa	A/C in between clouds. Widespread intense convection left of track and scattered ahead of track. Low over MP with east-west trough extending to northeast Arabian Sea
3.	24 Aug 2002	1305 to 1321 (16 m)	18,000' (5400m) to 20,000' (6000m)	15°55' N, 72°21' E to 15°21' N, 72°10' E	Goa to point 'C' (16° N / 72° E) and point 'C' to point 'E' (14.5° N/72.3° E)	Overcast sky. Scattered convective cells extending beyond 20,000 feet. Off shore trough extending from north Gujarat to Kerala

Discussion − The map depicting the track of the aircraft and the position where icing was encountered is shown in Fig. 1. The icing was encountered at about 300 km from Goa at an altitude of 17,000 ft. The aircraft was flying in between the clouds and sky condition was overcast. The icing took place on the wiper of the front screen of the aircraft (Fig. 2). The icing was mostly glazed. The activated deicing equipment was unable to prevent the icing, indicating that probably a large number of supercooled water droplets were prevailing at the flight level. The heating provided by the deicing equipment was unable to raise the temperature of the aircraft screen to above zero degree resulting in icing. The METEOSAT cloud imagery (VIS/IR) at 0700 UTC indicated very intense convection over the area (Fig. 3). The airborne aircraft radar also showed cloud echoes extending higher than 20,000 ft. The ambient air temperature recorded by the aircraft thermometer was −7° C to −8° C. The wind velocity recorded abroad aircraft, based on the GPS system, indicated large horizontal wind shear (Table 2). Comparing these winds with the RS/RW data at 0000 UTC and 1200 UTC of Goa, brings out that the wind speed at Goa was much lighter and the ambient air temperature was warmer by 4 to 5° C as compared to the aircraft position. The isohygric indicated the water content to be 8 gm/kg at 20,000 ft at Mumbai. Much cooler and sub zero temperature at the aircraft location coupled with horizontal wind shear, advancing phase of monsoon with very moist air resulted in considerable accumulation of liquid water in vicinity of the convective clouds at the aircraft flight level, resulted in glazed ice formation.

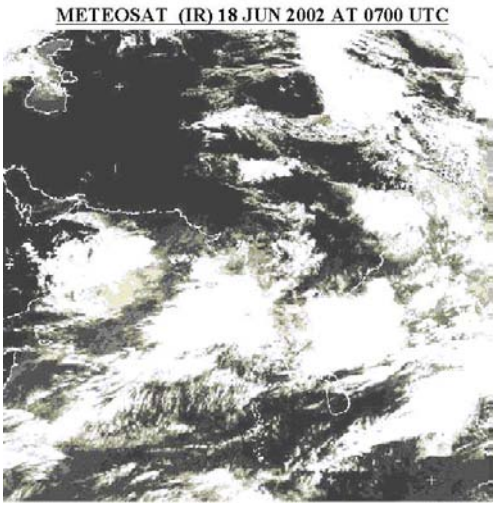

Fig. 3. METEOSAT cloud imagery (IR) at 0700 UTC of 18 June 2002

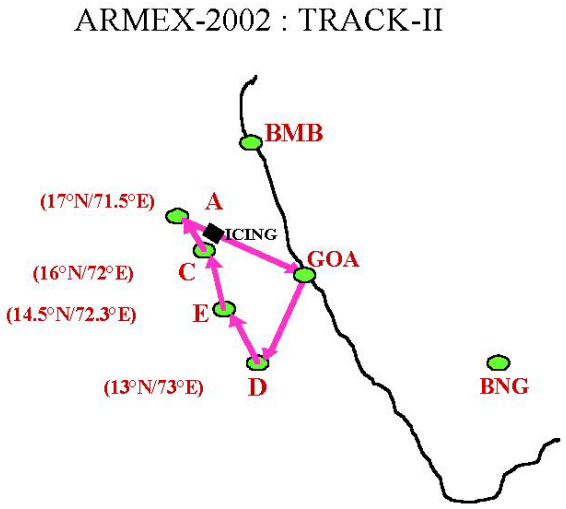

Fig. 4. Track of the aircraft and position where icing was encountered

TABLE 2

(a) Radio sonde data

Morning (0000 UTC) ascent of Goa Date : 18 Jun 2002			Evening (1200 UTC) ascent of Goa Date : 18 Jun 2002		
Ht (feet)	Dir/speed (°/kt)	Temp (°C)	Ht (feet)	Dir/speed (°/kt)	Temp (°C)
2,000	270/15		2,000	270/20	
5,000	290/10		5,000	270/20	+17
10,000	240/25	+14	10,000	270/30	+04
15,000	290/25	-	15,000	-	-
18,000	290/10	-02	18,000	310/10	-06
20,000	350/15	-08	20,000	320/10	-08
24,000	340/15	-22	24,000	-	-
30,000	020/25	-32	30,000	-	-

(b) Airborne observation data

Level (feet)	Time (IST)	Temp (°C)	Position of the aircraft		GPS wind		Clouds	Aircraft with respect to clouds
			Lat.	Long.	Dir (°)	Speed (kt)		
20,000	1259	-08	17° 00′	71° 30′	247	30	Overcast	Between
20,000	1302	-08	16° 57′	71° 42′	235	14	Overcast	Between
20,000	1308	-07	16° 42′	72° 03′	224	19	Overcast	Between
20,000	1310	-07	16° 34′	72° 13′	235	16	Overcast	Between
20,000	1314	-07	16° 24′	72° 27′	235	16	Overcast	Between
19,000	1315	-07	16° 20′	72° 31′	246	24	Overcast	Between
18,000	1316	-05	16° 18′	72° 34′	234	28	Overcast	Between
17,000	1317	-04	16° 15′	72° 38′	249	34	Overcast	Between

PHOTOGRAPH OF ICING ON COCKPIT WINDOW

Date/Time : 26 Jun 02/1302 IST Altitude : 20000 feet

Location : BETWEEN POINT A AND GOA (16.46/71.58)

Fig. 5. Photograph showing the icing on cockpit window

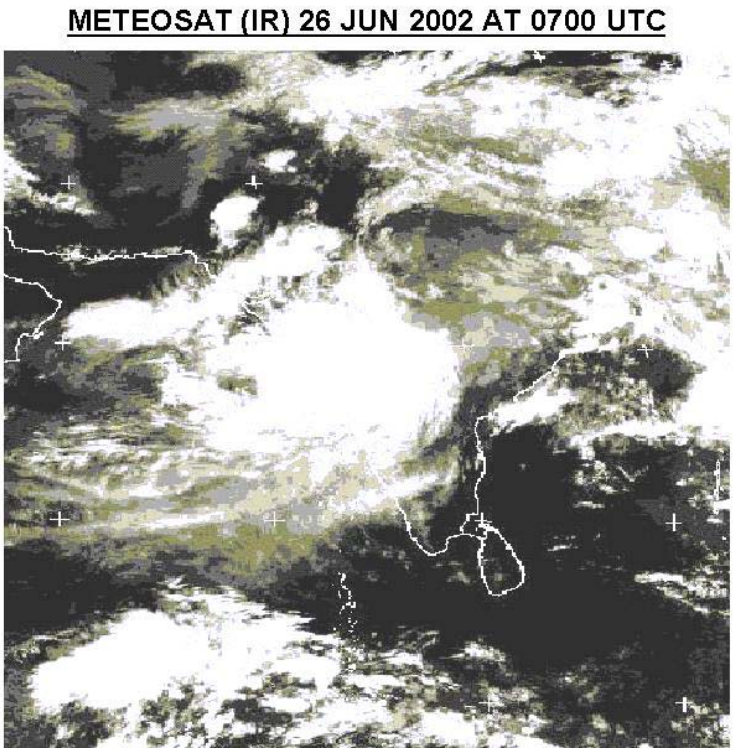

Fig. 6. METEOSAT (IR) cloud imagery at 0700 UTC of 26 June 2002

TABLE 3

(a) Radio sonde data

Morning (0000 UTC) ascent of Goa Date : 26 Jun 2002			Evening (1200 UTC) ascent of Goa Date : 26 Jun 2002		
Ht (feet)	Dir/Speed (°/kt)	Temp (°C)	Ht (feet)	Dir/Speed (°/kt)	Temp (°C)
2,000	290/30		2,000	270/25	
5,000	270/35	+18	5,000	270/25	+19
10,000	290/30	+10	10,000	290/25	+10
15,000	270/25	--	15,000	270/20	+02
18,000	270/20	-04	18,000	250/25	-02
20,000	--	--	20,000	250/40	-08
24,000	250/30	-15	24,000	250/50	-11
30,000	050/10	-30	30,000	190/20	-28

(b) Airborne observation data

Level (feet)	Time (IST)	Temp (°C)	Position of the aircraft		GPS wind		Clouds	Aircraft with respect to clouds
			Lat.	Long.	Dir(°)	Speed(kt)		
20,000	1259	-06	16° 58'	71° 45'	003	10	Overcast	Between
20,000	1301	-06	16° 51'	71° 54'	232	07	Overcast	Between
20,000	1302	-06	16° 43'	72° 03'	279	04	Overcast	Between

3.2. *Case – II : 26 June 2002*

Synoptic features − On 21st June, a low pressure area formed over Bay moved inland and was located near west Madhya Pradesh on 26th June with east-west trough extending from the system to NE Arabian Sea. The Satellite imagery was showing intense cloud mass associated with the system extending up to NE Arabian Sea placed as Fig. 6.

Discussion − Like in the previous case, this time too, at the time the aircraft passing through in the vicinity of the convective cells, the aircraft experienced the icing (Fig. 5). During the episode the aircraft was in between the clouds and sky condition was overcast. The map depicting the track of the aircraft and position where icing was encountered (Fig. 4) shows that the episode occurred off Goa coast. In satellite imagery (IR) of 0700 UTC, the intensive cloud mass associated with the synoptic system extending up to NE Arabian Sea, was seen over entire west coast and the adjoining Arabian Sea (Fig. 6). However, while flying off Goa coast, the intense convective cells were seen left of the track extending from 20 km onwards along entire coastline as depicted in the photograph of weather radar console taken at the time of occurrence of the episode at 20,000 ft. A few feeble patches ahead of the aircraft track were also observed at that time in the photograph of radar console.

The wind direction showed the variation from northerly to south-westerly within two minutes and then changing to westerly within one minute. The changes in speed were from 10 knots to 4 knots within three minutes. It showed that temporal variation in the wind data is quite significant in the vicinity of the convective activities. The evening ascent of Goa (Navy) showed the wind at 20,000 ft as 240/23 knots. It showed marked difference from the GPS winds recorded onboard at 1300 hr (IST). Further, the large and rapid changes in the wind direction and speed indicated sheer and interaction of the convective cloud motion with the environment. The depth of moist layer (8 gm/kg) was recorded in the evening

ascent extending up to 485 hPa showing high water content in the atmosphere. The temperature remained –6° C throughout the episode which was same as RS data of Goa. The aircraft data and available radio sonde data has been placed in the Table 3.

This episode brought out that even satellite imagery showed the overcast cloud mass along the track, the aircraft radar showed widespread convective cells left of the track whereas the right of the track only isolated patches were observed extending beyond 20,000 ft. Further, the variation in the wind data at that level of aircraft in the vicinity of convective clouds undergoes significant changes.

3.3. *Case III : 24 August 2002*

This case took place late in August 2002. It occurred off Konkan coast (between 16° N / 72° E and 14.5° N/ 72.3° E) and type of icing was observed to be rime between 18,000 ft and 20,000 ft levels. The last case of icing also confirms to the observation in the previous two cases, therefore the further details and figures have been omitted in this paper.

4. Conclusion

The icing is a well known aviation weather hazard which is encountered while flying in the atmosphere where the temperatures are subzero. During ARMEX phase-I, there were two episodes of light clear icing and one of trace rime icing. All the episodes were encountered close to Goa coast. The flight level for encountering icing was found to be between 17,000 ft and 20,000 ft. The favorable temperature for ice formation was found to be –6° C to –8° C in the close vicinity of convective cells where large number of super cooled water drops can exist. Meso-scale intense convective cells as observed by onboard weather radar extended much beyond 20,000 ft. These cells are not uncommon during Indian monsoon season which results into heavy rainfall over west coast. The super cooled liquid drops found in the region of –6 to –8° C, were numerous and probably large enough to overcome the heating of deicing equipment and gave rise to glazed/rime icing on the wind screen of the aircraft.

Reference

Terry, T. Lankford, 2001, “Aviation Weather Handbook”, Ch – 24, 1-16.