Norwegian Safety Investigation Authority

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REPORT SL 2020/16

REPORT ON SERIOUS AVIATION INCIDENT WEST OF FØRDE AIRPORT BRINGELAND ON 14 NOVEMBER 2016 INVOLVING ATR 72-212A, OY-JZC, OPERATED BY JET TIME AS

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the NSIA's task to apportion blame or liability. Use of this report for any other purpose than for flight safety shall be avoided.

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

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On 1 July 2020, the Accident Investigation Board Norway (AIBN) took over the task as investigating authority for accidents and serious incidents in the Norwegian Armed Forces. From the same day, the name was changed to Norwegian Safety Investigation Authority (NSIA). The name has not been changed in the text in this report, because the work was almost completed when the change was done.

REPORT CONCERNING A SERIOUS AVIATION INCIDENT

Type of aircraft:	ATR-GIE Avions de Transport Régional ATR 72-212A
Nationality and registration:	Danish, OY-JZC
Owner:	NAC Aviation 3 A/S, Denmark
Operator:	Jet Time AS
Crew/commander:	2 pilots and 2 cabin crew members, no injuries
Passengers:	36 passengers, no injuries
Location:	The airspace between Sognefjorden and Sunnfjord, approximately 70 nautical miles north-northeast of Bergen
Time of the incident:	Monday 14 November 2016. 0810 hours.

All times given in this report are local time (UTC + 1 hour) unless otherwise stated.

NOTIFICATION OF THE INCIDENT

The Accident Investigation Board Norway (AIBN) was notified of the incident by Jet Time AS and by the Danish Accident Investigation Board on Wednesday 16 November. The commander filed a Flight Safety Report on the day of the occurrence. The report was originally classified as an incident report and submitted to Jet Time AS and the Danish Transport Construction and Housing Authority. The company later upgraded the report to a serious aviation incident. Pursuant to ICAO Annex 13 "Aircraft Accident and Incident Investigation", the AIBN notified, among others, the French accident investigation authority (BEA) as well as the Accident Investigation Board Denmark. The European Aviation Safety Agency (EASA) was also notified.

Accredited representatives from the BEA (assisted by advisors from the aircraft manufacturer ATR) as well as the Accident Investigation Board Denmark assisted the AIBN in the investigation. EASA has also contributed with a technical advisor.

SUMMARY

Flight SAS4144 from Bergen to Ålesund was operated by the Danish airline Jet Time AS on behalf of SAS. En route to Ålesund, control of the aircraft was temporarily lost in severe icing[1] conditions. The control loss occurred in the airspace just west of Førde Airport Bringeland as the crew had started to change course to escape the icing conditions.

The crew regained control of the aircraft and continued its flight to Ålesund where it subsequently landed as normal. No people on board were injured, nor was there any damage to the aircraft.

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[1] A commonly used definition of severe icing is that the ice accretion rate exceeds the capacity of the aircraft's ice protection systems. This means that icing conditions characterized as severe icing for one aircraft type may not be severe for other types. The checklist for the relevant aircraft type states that the aircraft must escape such icing conditions: "*SEVERE ICING CONDITIONS ……… ESCAPE*".

The AIBN is of the opinion that the loss of control was the result of a combination of insufficient planning and inappropriate decisions en route, particularly the crew's attempt to climb above the icing conditions despite degraded aircraft performance as well as incorrect use of the autopilot.

Control recovery may have been impeded by the commander's initial response, pulling the control wheel back as the stick shaker[2] activated. The commander is likely to have become startled when the stick shaker activated and the autopilot automatically deactivated, while the aircraft at the same time suddenly banked sharply and simultaneously pitched nose down. He may consequently have pulled the control wheel back due to the so-called startle effect.

Another contribution to the non-optimal control recovery was that two memory items[3] on the checklist for stalling, deploying flaps and increasing engine power, were omitted. However, the crew quickly regained their composure and the rest of the flight and landing in Ålesund proceeded without any further problems.

AIBN is of the opinion that icing should be a priority item in risk analyses for airlines when planning to operate in Norway during the icing season, and that it is important to take the characteristics of the aircraft type into account. Such analysis should conjointly consider the flown routes, the flown flight levels, expected icing conditions, and mitigation actions to adverse conditions including icing, with regard to the aircraft type and specific performance.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Introduction

The description of the course of events is mainly based on data from the aircraft's Flight Data Recorder (FDR), interviews with the crew, recordings of radar and communication from Avinor, as well as interviews with two of the aircraft's passengers. The AIBN has not had access to recordings from the aircraft's Cockpit Voice Recorder (CVR). More details about the flight recorders are available in Chapter 1.11.

1.1.2 The flight

1.1.2.1 The Danish airline Jet Time AS was leased by Scandinavian Airlines System Denmark-Norway-Sweden (SAS) to operate flights in Western Norway. A turboprop aircraft of the ATR 72-212A type was used for Flight SAS4144, Bergen – Ålesund – Trondheim.

1.1.2.2 The crew assembled at 0640 hours on the morning of Monday, 14 November 2016 to plan the first flight of the day. The flight was from Bergen Airport Flesland (ENBR) to Trondheim Airport Værnes (ENVA) with a transit stop at Ålesund Airport Vigra (ENAL). Among other things, they noted that moderate icing was forecast for the first flight leg. At Bergen Airport Flesland (ENBR), the temperature was 7 degrees Celsius, with a south-south-easterly fresh breeze with scattered, low clouds and rain. As they taxied to the take-off position, the crew activated the anti-icing system for both propellers

[2] Stick shaker is an automatic stall warning system. It is a mechanical device that generates vibrations and a rattling noise in the control wheel, indicating that an aircraft is close to the critical angle of attack and stall is imminent. In such a situation, the crew must push the control wheel forward to reduce the angle of attack and prevent stalling.

[3] A "Memory Item" or "Boxed Item" is a checklist item that pilots must know by heart.

and the side windows, as well as for the aileron, elevator and side rudder horns. They also activated the de-icing system on the wings' leading edges, horizontal stabilizer and tail fin for one minute and 35 seconds, also while taxiing. More details about the aircraft's ice protection systems are available in Chapter 1.6.

1.1.2.3 At 0749 hours, SAS4144 took off from runway 17. The first officer was the Pilot Flying (PF), while the commander was the Pilot Monitoring (PM).

1.1.2.4 After take-off towards the south, the aircraft made a right turn, which meant the initial part of the climb took place above the sea to the west. The commander thought this would be advantageous in order to gain some altitude before heading inland where the risk of icing would be greater. The crew set the course north, activated the autopilot at a selected airspeed of 170 kt, while climbing towards the cleared flight level, FL190[4]. They expected the icing to decrease above FL140.

1.1.2.5 As they climbed through flight level FL100, the aircraft's electronic icing detector indicated icing. Five seconds later, the crew activated the aircraft's de-icing systems. The de-icing systems remained activated until the aircraft had landed. The commander has explained that icing began at approx. FL100 and became more intense the higher they climbed.

1.1.2.6 Taking into account the aircraft's take-off mass, the minimum operating speed (Vmin OPS)[5] in icing (icing bug speed) was 156 kt according to the Airplane Flight Manual (AFM).

1.1.2.7 According to the first officer's statement, ice started to form on the aircraft as it passed FL120. According to the Flight Data Recorder, the vertical speed (rate of climb) was 765 ft/min when the aircraft passed FL127. Furthermore, the data show that during this period the vertical speed dropped by half in 30 seconds.

1.1.2.8 As the aircraft passed FL137, the Aircraft Performance Monitoring system (APM) displayed the following alert: *DEGRADED PERF.* Almost simultaneously, at FL140, the first officer observed two streaks of water or ice running on her window. She interpreted this as an indication of freezing rain and informed the commander. Both crewmembers also observed ice forming on the side windows.

1.1.2.9 The crew increased the power to maximum permitted continuous power (PWR MGT selector to MCT) in order to increase the propellers' rotational speed so that the ice would detach from the propeller blades. Selected airspeed was reduced to 165 kt.

1.1.2.10 As the aircraft passed FL160, a new APM alert was displayed: *INCREASE SPEED*. The indicated airspeed was then 164 kt. At this altitude, the selected airspeed was increased back to 170 kt, the aircraft levelled off and the airspeed increased to 172 kt. After a short discussion, the crew agreed to terminate the climb. They wanted to reduce the altitude in order not to lose any more speed, and to change the course further west towards the sea.

1.1.2.11 After the commander had obtained clearing from air traffic control, a descent towards FL150 was initiated. The autopilot was still engaged. The descent took place at a vertical velocity (sink rate) of approx. 500 ft/min. Shortly after the descent was initiated, the

[4] FL190 is about 19,000 ft

[5] The FCOM defines Vmin OPS as: "*Minimal flight speed according to flying conditions and aircraft configuration*".

engine power was reduced from the maximum continuous thrust (MCT) to cruise (CRZ). The airspeed then stabilized at approx. 170 kt. The autopilot altitude capture and altitude hold modes were also activated. As the altitude decreased towards FL150, ALT CAPTURE engaged. Thereafter ALT HOLD maintained FL150. After having been established at FL150, the airspeed started to decrease and the angle of attack to increase. The commander has explained that he noticed that the aircraft did not accelerate.

1.1.2.12 The crew observed more and more ice forming on the airframe. They informed Norway Control and requested clearance to turn in a westerly direction. Having received clearance from Norway Control, the crew selected 330° using the autopilot heading knob. The autopilot initiated a turn to the left in the high bank mode. The bank angle in the turn was 29.4°.

1.1.2.13 Twelve seconds into the turn, the autopilot automatically deactivated. At the time, the airspeed was 163 knots and the local angle of attack had reached 11.8°. The banking towards the left increased abruptly, and at the same time, the stick shaker activated. The first officer reacted by trying to push the control wheel forward. In addition, she responded by right rudder pedal input and turning the control wheel to the right. However, the bank angle still increased uncontrollably to 68.2° left.

1.1.2.14 At the same time, the commander took hold of the control wheel, initially pulling back, in the opposite direction of the first officer’s move[6]. The first officer has explained to the AIBN that she tried to push the aircraft's nose down when the stick shaker activated. She noticed that it was unusually difficult to push the control wheel forward and wondered if ice had formed on the horizontal tail[7].

1.1.2.15 The crewmembers have explained that they both operated the controls during this phase. The commander did not take over the controls, but "joined her" on the control wheel to help her regain control of the aircraft. According to their statements in retrospect, neither of them was aware of the fact that the other gave an opposite elevator input. Both crewmembers have stated that they thought cooperation and communication between them were good.

1.1.2.16 As the aircraft banked sharply to the left, the nose pitched down to 3.3° below the horizon. Immediately after, the aircraft banked uncontrollably to the right and the nose pitched further down to 8.1° below the horizon. However, the angle of attack had increased to 14.5°. The stick shaker and stick pusher[8] then activated for two seconds. The bank angle to the right reached 66.2° before it reversed back to the left. This time, the bank angle to the left stopped at 36°. The first officer continuously responded to the uncontrolled banking with opposite rudder and aileron inputs.

[6] In his comment to the draft version of this report, the commander has explained that airspeed had increased at this point and that they consequently had gathered more lift. In order to avoid more distress for the passengers than necessary, he wanted to reduce the nose pitch down. He pulled back on the control wheel, but did not have time to inform the first officer about this. After a few seconds, pitch down was reduced and he released the backpressure on the control wheel. He has written that he remembers the situation quite clearly.

[7] The opposite forces were not large enough to activate the pitch uncoupling mechanism between the left and right elevators. Thus, pitch disconnect is not an issue in this incident.

[8] Stick pusher is an automatic system to prevent stalling. If the crew do not push the control wheel forward when the stick shaker activates, the stick pusher will automatically push the control wheel forward to reduce the angle of attack and thus prevent stalling. On ATR 72, the stick pusher pushes the control wheel forward with a force of 40 daN.

1.1.2.17 Three seconds after their first activation, the stick shaker and stick pusher activated again. The local angle of attack was then 15.9°. Two seconds later, the nose pitched to 11.9° below the horizon and the aircraft quickly lost altitude while the airspeed increased to 190 knots. At the most, the sink rate was 6,448 ft/min before the nose started to pitch up again.

1.1.2.18 When asked directly during separate interviews with the AIBN, both crew members stated that they did not notice that the stick pusher activated (see Section 1.11.2.4).

1.1.2.19 At its lowest, the aircraft was at an altitude of 13,425 ft, before it started to ascend again. According to the ICAO Aeronautical Chart Southern Norway, the minimum safe altitude for terrain and obstruction clearance was 5,800 ft in the area where control of SAS4144 was lost. This meant clearance to terrain and obstructions was 7,600 ft or more. The aircraft's course (330°) took it to areas with lower terrain height.

1.1.2.20 During stall recovery, the nose pitched up to 12.1° above the horizon. Altitude increased again, while the speed decreased. The crew reacted by selecting maximum continuous thrust (PWR MGT selector to MCT) and pushing the power levers forward from 70° to 77°. Despite this, the APM indicated almost immediately: *INCREASE SPEED*. 13 seconds had then passed since SAS4144 started its climb. The APM message was displayed for 28 seconds. SAS4144 then climbed about a thousand feet to the highest registered altitude of 14,531 ft. The speed had then dropped to 150 kt.

1.1.2.21 The crew requested clearance to descend and initiated a continuous descent towards FL100. Norway Control gave SAS4144 clearance to operate within altitude block FL100 – FL140. SAS4144 continued on course 330, along a more westerly route than originally planned. This meant they flew closer to the coastline and lower terrain.

1.1.2.22 At 08:13:36 hours, SAS4144 descended below FL127. The airspeed at the time was 212 kt, and the ice that had formed on the airframe started to disappear. The crew reconnected the autopilot 3 minutes and 23 seconds after the autopilot automatically deactivated and temporary loss of control occurred. When the aircraft reached FL110, all the ice had disappeared and the *DEGRADED PERF.* alert from APM, which had displayed continually since 08:00:08, discontinued.

1.1.2.23 After the situation was resolved, the commander informed the aircraft passengers over the PA system.

1.1.2.24 With the exception of the APM alert *DEGRADED PERF.* displaying an additional two times, at, 08:18:58 and 08:20:33 respectively[9], the rest of the flight passed without incident. SAS4144 landed at Ålesund Airport Vigra, at 0837 hours, 48 minutes after departure from Bergen Airport Flesland.

1.1.2.25 After landing in Ålesund, the aircraft had a 20-minute transit stop before continuing to Trondheim. The first officer went into the cabin and told the cabin crew that the aircraft had been exposed to icing but did not provide any further details about the incident. Except for the commander's announcement just after control of the aircraft had been regained, there was no passenger briefing.

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[9] Both times the alert was on for 40 seconds.

1.1.2.26 Neither the commander nor the first officer felt uncomfortable about going on to the other flights of the day. Consequently, neither considered declaring themselves unfit for further service. Both flew another three legs before leaving work that day.

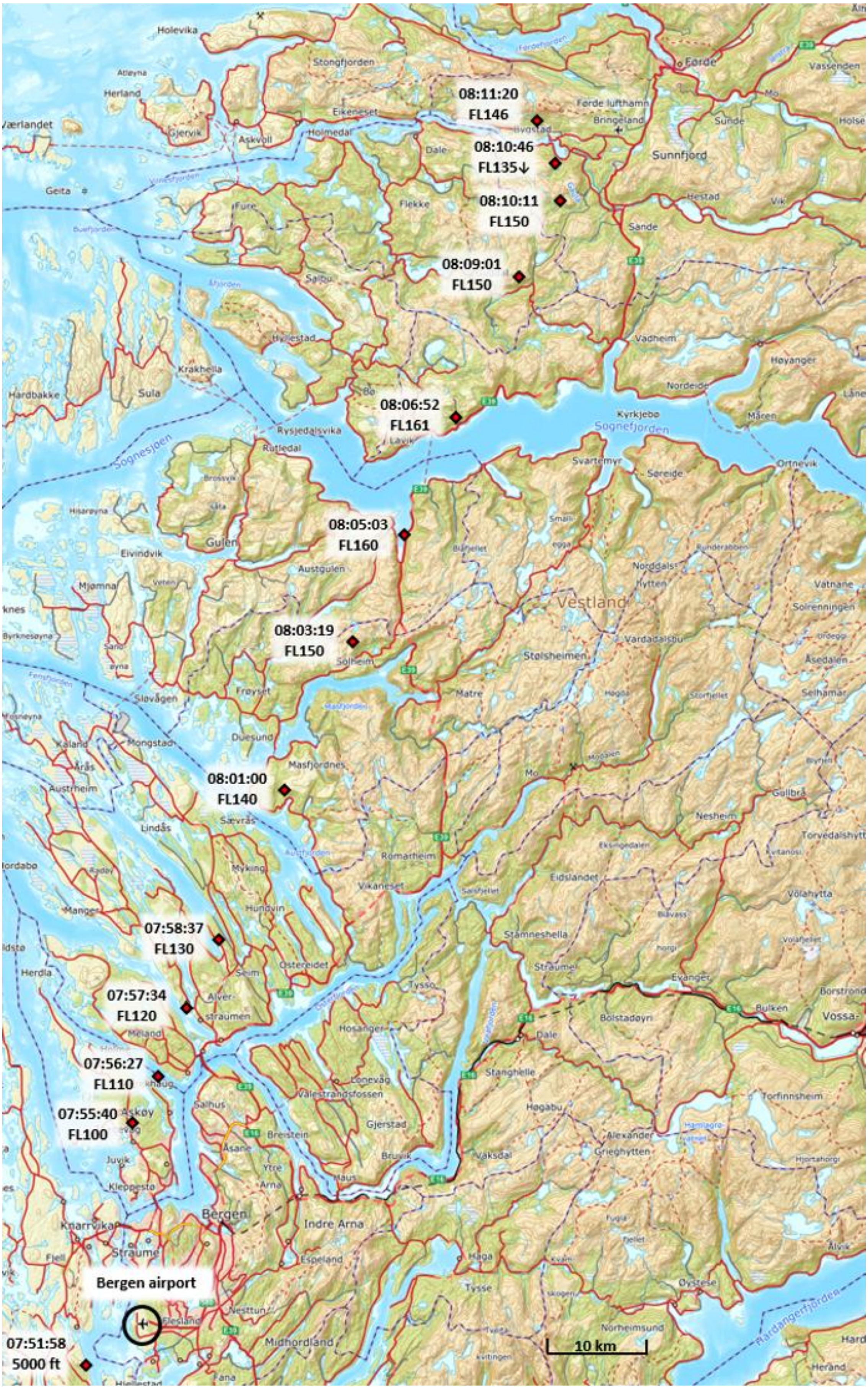

Figure 1: The map plot showing SAS4144's flight levels (FL) and positions at given times. The plot is based on radar data from Avinor. Illustration: AIBN

1.1.3 Interviews with passengers

1.1.3.1 The AIBN interviewed two passengers in connection with the incident. Both are experienced air travellers who are used to travel by air in Norway in the autumn and winter.

1.1.3.2 One of the passengers held a private pilot's licence. He was seated in row 2 on the right side of the cabin, where he had both seats to himself. From his seat, he could see the right engine and propeller as well as much of the wing's leading edge outside of the engine nacelle. The passenger has stated that he could no longer see the ground beneath him due to clouds a fairly short time after take-off from Bergen, and that he observed an increasing amount of white ice forming on the leading edge of the wing as well as on the propeller spinner and the engine nacelle. He described the clouds as light grey.

1.1.3.3 The passenger saw that the de-icing boots operated continually, and he heard irregular cracking sounds coming from the fuselage sides, which he presumed was ice shedding from the propeller blades. Furthermore, at one point the propeller's rotational speed seemed to increase. Simultaneously, he noticed that the cracking sounds on the airframe decreased.

1.1.3.4 The passenger observed that the de-icing boots did not manage to remove all the ice. He also saw that the ice along the wing's leading edge changed character and colour. It seemed clearer and more translucent.

1.1.3.5 As the aircraft stopped climbing and apparently levelled out, the passenger noticed that the aircraft started buffeting. He identified this as the initial stage before a stall, and as a pilot, he found it strange that the crew did not lower the nose of the aircraft to prevent this. He noticed that the wing dipped sharply and that the nose of the aircraft pitched sharply down, which convinced him the aircraft had stalled. The passenger feared the worst and that he would not survive. He noticed that other passengers on the aircraft were screaming.

1.1.3.6 After the situation had been resolved, the passenger heard the commander make an announcement on the PA system, informing the passengers that the crew had regained control of the aircraft. The passenger interpreted this as confirmation of the severity of the situation that had occurred and expected to receive more information about the incident after the aircraft had landed in Ålesund. He expressed disappointment that this did not take place.

1.1.3.7 The other passenger was seated on the left side of the aisle, right behind the wing. He could not see the wing's leading edges or the engine nacelle, nor did he observe any ice on the aircraft. The passenger described the clouds as light grey, similar to snow cover.

1.1.3.8 This passenger also felt the aircraft shaking just before each wing drop. He described it as driving on a "washboard road". He also stated that the wing drops were severe and that the nose of the aircraft pitched sharply down. He had never experienced anything like it before.

1.1.3.9 Just as the first passenger, he interpreted the commander's announcement that the crew had regained control of the aircraft as confirmation that the incident had been serious.

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	4	36	

1.3 Damage to aircraft

No damage to the aircraft was registered as a result of the incident.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander

1.5.1.1 The commander was 60 years old. He completed his commercial pilot training in South Carolina, USA. Before joining Jet Time AS, he worked for a number of different airlines in Sweden, Norway, Finland and Denmark, where he had operated turboprop aircraft such as Jetstream, ATP and ATR 42/72. The commander was employed by Jet Time AS in 2014. He held a valid European ATPL (A) from Sweden. Furthermore, he had valid type rating for ATR 42/72/IR, as well as a valid medical certificate, class 1, which required him to wear corrective spectacles (VNL).

Table 2: Flying hours commander

Flying hours	All types	Relevant type
Last 24 hours	4	4
Last 3 days	11	11
Last 30 days	69	69
Last 90 days	163	163
Total	9,423	3,523

1.5.1.2 The commander had not completed the company's annual Upset Prevention and Recovery Training – UPRT when the incident occurred (see Section 1.17.1.4).

1.5.1.3 The commander arrived in Bergen in the afternoon before the day of the incident and stayed overnight in a hotel. He has stated that he had had sufficient rest and food before the flight in question.

1.5.2 First officer

1.5.2.1 The first officer was 51 years old. She completed her commercial pilot training in Arizona, USA. Before joining Jet Time AS, she worked for another Danish operator, where she accumulated almost 6,000 hours total flying time on various versions of ATR 42. The first officer was employed by Jet Time AS in April 2016. She held a valid European CPL (A) issued in Denmark. Furthermore, she had valid type rating for ATR 42/72/IR CO-PILOT, as well as a valid medical certificate, class 1, which required her to wear corrective spectacles (VNL).

Table 3: Flying hours first officer

Flying hours	All types	Relevant type
Last 24 hours	4	4
Last 3 days	11	11
Last 30 days	19	19
Last 90 days	127	127
Total	7,000	5,850 (of which 270 was on the ATR 600 version)

1.5.2.2 The first officer had completed the company's annual Upset Prevention and Recovery Training – UPRT about two weeks before the incident occurred (see Section 1.17.1.4).

1.5.2.3 The first officer also arrived in Bergen in the afternoon before the flight and stayed overnight in a hotel. She had slept well and had breakfast before the flight.

1.6 Type of aircraft

1.6.1 <u>In general about ATR 42/72</u>

1.6.1.1 ATR 42 and ATR 72 are very similar two-engine turboprop aircraft with a passenger capacity of 50 and 70 seats, respectively. ATR 42 first entered service in 1984, whereas ATR 72 entered service in 1988. By year-end 2019, the French-Italian manufacturer GIE Avions de Transport Régional had delivered a total of 1 720 ATR 42/72 aircraft to companies across the world. There are multiple versions of both aircraft types.

1.6.1.2 ATR 42/72 has EASA type certificate number EASA.A.084.

1.6.2 <u>OY-JZC</u>

1.6.2.1 OY-JZC is an ATR 72-212A, which is the newest version of the seven ATR 72 variants. Type certificate for this version was granted on 10 August 2011. Together with the latest version of ATR 42, ATR 72-212A is marketed as the "600 version" or "ATR 72-600". The 600 version is characterized by its ATR New Avionics Suite, i.e. a new type of "glass cockpit".

1.6.2.2 OY-JZC has serial number 1120. The aircraft entered on the Danish aircraft registry 20 March 2014. It had a valid Danish Certificate of Airworthiness and a Danish Airworthiness Review Certificate (ARC), valid through 20 March 2017.

1.6.2.3 The aircraft has two Pratt & Whitney Canada PW127 M turboprop engines, each with a maximum take-off power output of 2,750 shaft horsepower (SHP), and two Hamilton Sundstrand 568F-1 propellers. The maximum permitted take-off weight (MTOW) is 23,000 kg.

Figure 2: OY-JZC in SAS colours. Photo: Valentin Hintikka[10]

1.6.2.4 According to the load manifest, the aircraft had a take-off mass of 19,320 kg, and was loaded within the applicable mass and centre of gravity limitations specified in the aircraft flight manual (AFM) prior to departure from Bergen.

1.6.3 Modifications to improve banking stability in icing conditions and in the event of stalling

1.6.3.1 Compared with the earlier versions of ATR 72, ATR 72-212A has modified icing protection. Among other measures, the following modifications had been made to improve longitudinal axis stability (banking stability) in icing conditions. The inflatable de-icing boots on the wings' leading edges were widened in front of the ailerons. They were extended from 6% backwards along the wing chord to 12%. The ailerons were changed from servo-tab ailerons to spring-tab ailerons. The latter is considered to provide improved feedback on the control wheel and better aileron authority at low speeds in severe icing conditions. Chapter 1.18.3 describes issues related to banking stability.

1.6.3.2 ATR 72-212A (600 version) is in addition equipped with various icing protection systems. These are described in Sections 1.6.4 – 1.6.8 below.

1.6.4 Anti-icing advisory system – AAS

1.6.4.1 The anti-icing advisory system – AAS is designed to notify and guide the crew to ensure they apply the correct procedures should the aircraft enter icing conditions, such as:

- Increase minimum operation and manoeuvring speeds and activate the anti-icing systems.
- Activate the de-icing systems at the first indication of ice accretion on the aircraft.
- Switch off the de-icing systems as soon as ice has stopped forming on the aircraft.

[10] The photo is unedited. It is used according to licence: https://creativecommons.org/licenses/by-sa/2.0/legalcode

1.6.4.2 In addition to various information and warning lights in the cockpit, AAS includes two external icing sensors:

1. The ice detector is an electronic sensor located under the left wing. As soon as ice forms on the sensor, the crew will be informed by an amber caution light with the text *"ICING"* on the Flight Mode Annunciator (FMA) on upper part of the Primary Flight Display (PFD). The warning light stay continuously on as long as there is ice accretion on the Ice Detector.

2. Ice Evidence Probe is a probe (visual sensor) that protrudes into the airstream near the left cockpit window. The sensor functions as a visual indicator of ice accretion. The Ice Evidence Probe is lit up so that it can also be used in the dark. The Ice Evidence Probe is designed and positioned to ensure that any ice on the probe remains until the entire aircraft is free of ice.

1.6.5 Wing lights

1.6.5.1 There is one light on either side of the fuselage. They light up the leading edges of the wings as well as the engine air inlets. This makes it possible to observe ice accretion in the dark.

1.6.6 Aircraft Performance Monitoring – APM

1.6.6.1 The Aircraft Performance Monitoring system – APM uses data from the following main sources: Air Data Computer, Engine Electronic Computer, Flight Management System, Fuel Computer Unit and Core Avionics Cabinet. These data are used to calculate the aircraft's theoretical (expected) performance, such as drag, and then compare to the actual performance. If drag is higher than it should be in theory, the system assumes that the aircraft is affected by icing and displays a visual warning together with an aural alert:

- *CRUISE SPEED LOW* – CRZ SPD LO is the first warning level. It reports that the cruising speed is 10 kt lower than calculated and that there is a slight increase in drag. There is no audible signal.

- *DEGRADED PERFORMANCE* – DGD PERF warns of abnormal drag increase due to potential severe icing.

- *INCREASE SPEED* warns that the cruising speed is lower than the minimum speed for icing conditions (Minimum Severe Icing Speed – MSIS) + 2 kt.

1.6.7 Pneumatic de-icing

1.6.7.1 Pneumatic de-icing are ice-removing systems consisting of inflatable rubber boots on the wing's outer and inner leading edges, on the leading edges of the horizontal stabilizer, on the engines' air inlet and inside the engines' air intake gas path. The de-icing boots are inflated with bleed air from the engines. The bleed air inflates the de-icing boots to a pressure of 1.4 bar to detach any ice that may have formed on the surface of the boots. The de-icing boots are inflated sequentially in cycles[11] that start automatically each 60 (FAST MODE) or 180 (SLOW MODE) seconds, depending on whether the outside air

[11] Each cycle normally lasts for 40 seconds.

temperature is above or below -20°C. Pneumatic de-icing does not prevent ice accretion but can remove ice that has already formed.

1.6.7.2 According to FCOM 2.02.08, the crew were to activate de-icing when ice started forming on the aircraft.

1.6.8 Electric heating – anti-icing

1.6.8.1 The windscreens and parts of the cockpit side windows, the propeller blades, and all flight control horns and a number of external sensors, such as the pitot tubes, angle of attack sensors and static pressure openings, have electric heating. Electrical heating can both remove ice and prevent new ice from forming.

1.6.9 Operational limitations in icing conditions

1.6.9.1 There are two switches to activate electric heating of the flight control horns. The switches are marked:

- RUD and L ELEV

- AIL and R ELEV, respectively.

1.6.9.2 If one or both switches are activated, the following information is displayed in green: ICING AOA on the Ice Detector Panel on the instrument panel. Correspondingly, ICING AOA is displayed in green in the field for Flight Mode Annunciator (FMA) on the primary flight display (PFD).

1.6.9.3 As long as ICING AOA is displayed, several flight parameters are changed:

- Minimum speeds are increased, and relevant minimum icing speeds are displayed on the primary flight display (PFD).

- The angle of attack for activation of the stick shaker and for the stick pusher are reduced.

- Certain limitations are given in climbing instructions for collision avoidance (RA) in the Traffic Alert and Collision Avoidance System (TCAS).

1.6.9.4 It is not permitted to operate on autopilot if the aircraft encounters severe icing[12]. The reason is that the autopilot can block tactile indications of unfavourable changes in the aircraft's manoeuvring characteristics. Such tactile indications signal that serious control problems, or loss of control, may be imminent.

1.6.9.5 Flaps must not be deployed if the aircraft is holding in icing conditions[13].

[12] AFM 2_06 Page 2
[13] FCOM 2.02.08 P12

1.6.10 ATR flight operations manual system for ATR 72-212A

1.6.10.1 *Introduction*

ATR 72 has three different flight operations manuals, all of which discuss the issue of icing.

1.6.10.2 *Flight Crew Operating manual (FCOM)*

FCOM is the most comprehensive manual. It contains system descriptions, provides tables and graphs, as well as descriptions of performance characteristics, procedures and checklist references. In the introduction, the aircraft manufacturer writes that FCOM "*... may be used as a crew manual for training purposes and flight preparation.*"

FCOM has the most detailed descriptions of the aircraft systems and equipment for detecting and protecting against icing. Most of the chapter *Procedures and Techniques – Adverse Weather* is dedicated to icing and aircraft characteristics related to icing conditions. It includes a separate section, *Detection*[14], which describes symptoms and indications that will help the crew to decide whether the aircraft has encountered severe icing. FCOM also describes procedures related to icing, with references to the relevant checklists. The checklists are available in the Airplane Flight Manual (AFM) and in the Quick Reference Handbook (QRH).

1.6.10.3 *Airplane Flight Manual (AFM)*

AFM is the flight manual authorized by the competent authorities. It contains e.g. information about limitations, performance (including graphs and tables) and emergency procedures. AFM is not as comprehensive as F.C.O.M, but it, too, contains a description of symptoms and indications to help the crew determine whether the aircraft has encountered severe icing, *Severe Icing WARNING*[15]. In addition to procedures, the AFM also contains the checklists.

1.6.10.4 *Quick Reference Handbook (QRH)*

QRH is a simpler manual than AFM. The crews primarily use this manual during flights. The manual primarily contains procedures, checklists and tables. On the page that contains a checklist for severe icing, a section describes symptoms and signs to help the crew determine whether the aircraft has encountered severe icing. See *"Emergency 1.14 Severe Icing"* in Section 1.6.11.3.

1.6.11 Relevant procedures and checklists in QRH

During the icing incident involving OY-JZC, four procedures and checklists were of particular importance to the crew.

[14] FCOM 2.02.08 P13
[15] AFM 2_06 Page 2

1.6.11.1 *Degraded performance*

DEGRADED PERF

Mainly appears in level flight after CRUISE SPEED LOW or in climb, to inform the crew that an abnormal drag increase induces a speed decrease or a loss of rate of climb

The most probable reason is an abnormal ice accretion

R AIRFRAME DE-ICING ....CHECK ON
R IAS above ICING BUG + 10 KT..MONITOR
AP (if engaged) ....HOLD FIRMLY CONTROL WHEEL and DISENGAGE

■ **If SEVERE ICING conditions confirmed**
– or –
R ■ **If impossibility to maintain IAS above ICING BUG + 10 KT in level flight**
– or –
R ■ **If abnormal aircraft handling feeling**

R SEVERE ICING procedure (1.14) ....APPLY

■ **If normal conditions**

SCHEDULED FLIGHT..CONTINUE
ICING CONDITIONS and SPEED...................................MONITOR

R R <u>Note:</u> In case of APM messages "DEGRADED-PERF" or "INCREASE-SPEED" Vmin OPS automatically increased by 10 kt.

Figure 3: Checklist for "Degraded perf." warning. Source: QRH, 2.45 "Following Failures and Abnormal MPC"

1.6.11.2 *Increase speed*

INCREASE SPEED

Appears after DEGRADED PERF to inform the crew that the drag is abnormally high and IAS is lower than ICING BUG + 10 KT

■ **If abnormal conditions confirmed**

IMMEDIATELY PUSH THE STICK TO INCREASE SPEED
TO RECOVER MINIMUM IAS = ICING BUG + 10 KT

R SEVERE ICING procedure (1.09)..APPLY

R ■ **If normal conditions**

SCHEDULED FLIGHT..CONTINUE

ICING CONDITIONS and SPEED...................................MONITOR

R Note: In case of APM messages “DEGRADED-PERF” or
R “INCREASE-SPEED” Vmin OPS automatically increased by 10 kt.

Figure 4: Checklist for "Increase Speed" warning. Source: QRH, 2.45 "Following Failures and Abnormal MPC"

1.6.11.3 *Severe icing*

SEVERE ICING

MINIMUM ICING SPEED .... INCREASE by 10 kt
R PWR MGT ....MCT
R CL 1 + 2 ....100% OVRD
R PL 1 + 2 ....NOTCH
R AP (if engaged) ....FIRMLY HOLD CONTROL WHEEL and DISENGAGE
R SEVERE ICING CONDITIONS ....ESCAPE
R ATC ....NOTIFY

Note: In case of APM messages "DEGRADED-PERF" or "INCREASE-SPEED" Vmin OPS automatically increased by 10 kt.

- **If an unusual roll response or uncommanded roll control movement is observed :**

  Push firmly on the control wheel
  FLAPS ....EXTEND 15

- **If flaps are extended, do not retract them until the airframe is clear of ice.**

- **For approach, If the aircraft is not clear of ice :**

  GPWS .... FLAP OVRD
  STEEP SLOPE APPROACH (≥4.5°) ....PROHIBITED
  APP/LDG CONF ....MAINTAIN FLAPS 15
  APP SPEED ...... "REDUCED FLAPS 15 LDG icing speeds" + 5 kt
  Multiply landing distance FLAPS 30 by 2.12.

DETECTION

Visual cue identifying severe icing is characterized by ice covering all or a substantial part of the unheated portion of either side window

and / or

Unexpected decrease in speed or rate of climb

and / or

The following secondary indications :

. Water splashing and streaming on the windshield
. Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice
. Accumulation of ice on the lower surface of the wing aft of the protected areas
. Accumulation of ice on propeller spinner farther aft than normally observed

The following weather conditions may be conducive to severe in-flight icing :

. Visible rain at temperatures close to 0°C ambient air temperature (SAT)
. Droplets that splash or splatter on impact at temperatures close to 0°C ambient air temperature (SAT)

Figure 5: Checklist for "Severe Icing". Source: QRH, 1.14 "Emergency"

1.6.11.4 *Recovery after a stall or abnormal roll control response*

RECOVERY AFTER STALL
or ABNORMAL ROLL CONTROL

CONTROL WHEEL	PUSH FIRMLY
■ If flaps 0° configuration	
FLAPS	15°
PWR MGT	MCT
CL 1 + 2	100% OVRD
PL 1 + 2	NOTCH
ATC	NOTIFY
■ If flaps are extended	
PWR MGT	MCT
CL 1 + 2	100% OVRD
PL 1 + 2	NOTCH
ATC	NOTIFY

Note: this procedure is applicable regardless the LDG GEAR position is (DOWN or UP)

Figure 6: Checklist for "Stall Recovery or Abnormal Roll Control". Source: QRH, 1.15 "Emergency"

1.6.12 AUPRTA – Aeroplane Upset Prevention and Recovery Training Aid, and other ATR measures following the incident involving OY-JZC

1.6.12.1 Since 2014, ATR has coordinated changes to flight operations procedures in a new documentation format called EDORA[16]. Among other measures, comprehensive changes have been made to procedures relating to icing, both emergency procedures and regular procedures.

1.6.12.2 In cooperation with ICAO, Airbus, Boeing, Bombardier and Embraer, ATR issued "Aeroplane Upset Prevention and Recovery Training Aid – AUPRTA", revision 3 in February 2017. This is an online training aid based on ICAO Doc. 10011.

1.6.12.3 The purpose of this training aid is to improve the pilots' ability to recognize and prevent situations that can cause an aircraft to become uncontrollable, and to improve their ability to regain control should such a situation still arise.

1.6.12.4 Based on experiences, which indicate that pilots have found it difficult to identify external conditions such as icing intensity, ATR has adapted the AUPRTA manual procedures with a view to identifying objective criteria for providing better decision support for crews.

[16] EDORA – Electronic Documentation for Regional Aircraft

1.6.12.5 The training aid also emphasizes:

- Prevention in order to avoid risky situations through adequate pre-flight preparations
- Preventing loss of control through correct handling of the aircraft's energy (kinetic – potential – chemical)
- The ability to manoeuvre out of dangerous situations while at the same time keeping the aircraft's energy within acceptable limits.

1.6.12.6 In addition to issuing AUPRTA Issue 3, ATR amended FCOM as well as the Flight Crew Training Manual (FCTM) following the incident involving OY-JZC. The manufacturer also organized regional flight safety conferences in 2016 and 2018.

1.6.13 Recommended recovery technique in the event of wing drop and stalling

1.6.13.1 The recovery control procedure related to stalling or abnormal longitudinal axis movements (banking) (see Section 1.6.11.4) does not describe the use of rudder nor ailerons. However, FCOM 2.02.06 P 5 includes a cautionary note against the use of rudder.

2) RUDDER SHOULD NOT BE USED:

-To induce roll, except in the previous case(Aileron jam) or
-To counter roll, induced by any type of turbulence.
Whatever the airborne flight condition may be, aggressive, full or nearly full, opposite rudder inputs must not be applied. Such inputs can lead to loads higher than the limit, or possibly the ultimate loads and can result in structural damage or failure.

Figure 7: Guidelines for the use of rudder. Source: FCOM 2.02.06 P5

1.6.13.2 After this issue was raised in connection with this investigation, ATR has made it clear that it is the ailerons that must be used to level the wings, and that, in such a situation, the use of rudder should be avoided.

1.6.14 The condition of the icing protection systems on OY-JZC

1.6.14.1 During the last flights before the incident, the crew had experienced intermittent problems with the aircraft's temperature gauge. During a previous landing in Ålesund, the aircraft instruments showed an external temperature of 26°C, more than 16 degrees above the actual temperature. They suspected a fault in the aircraft's Core Avionics Cabinet (CAC). This was raised with maintenance personnel at Flesland Airport. In addition, the crew explained that the autopilot tended to sporadically disengage, for no apparent reason.

1.6.14.2 During taxiing before take-off from Flesland, the Electronic Ice Detector displayed a warning. The warning showed for 57 seconds. At the time of take-off, it was no longer displayed. The detector turned on again when the aircraft passed FL100 and entered icing conditions. It turned off three seconds before the stick shaker activated in connection with the loss of control.

1.6.14.3 Despite the irregularities mentioned in the paragraphs above, the AIBN has not found anything to indicate that any of the aircraft's icing protection systems were out of operation or did not function as intended, to the extent that this would have affected the course of events.

1.6.15 Change implemented after the OY-JZC incident

1.6.15.1 After the incident, the high bank protection was enhanced to take into account the APM degraded performance alert. If the APM has issued a *Degraded Perf*. warning, the high banking (30°) speed threshold will increase to $VmHB0_{icing}$ + 20kt.

1.6.16 Safety message from the manufacturer

1.6.16.1 ATR highlights the following points concerning icing:

- *Prepare the flight according to SOP* - "*watch your speed*"
- *Watch the rate of climb in climb: Below 300 FT/min, stop climbing, at 100 ft/min, descend*
- *Watch the speed in cruise: Maintain ATR Icing bug +10 or descend*
- *Trust* "*DEGRADED PERF*" *alert.*

1.7 Meteorological information

1.7.1 Weather report

Following the incident, the AIBN requested a weather report from the Norwegian Meteorological Institute covering the place and time of the incident. The report contains the following observations of the weather situation along the Bergen – Ålesund route during the time of the incident:

Low pressure in the north part of the Norwegian Sea caused a southerly wind in Western Norway south of Stad, building up to a strong gale of 22 m/s at Stad, abating somewhat further south. There was a warm front near the coastline.

These conditions are likely to have caused some icing. On the ground the wind came from the south, with a south-west to westerly wind higher up, thus causing an orographic lift of the air masses. Most likely, there was moderate icing in most places, somewhat more in areas where the orographic lift was strongest. SEV ICE SIGMET was discussed, but icing was considered to be moderate, although close to severe. After the SEV ICE report was received[17], new assessments were made according to the procedure, and a SEV ICE SIGMET was issued. No other cases of moderate or severe icing were reported.

The following AIRMET advised of icing along the route[18]:

WANO32 ENMI 140649

ENSV AIRMET B02 VALID 140700/141100 ENVV-

[17] From SAS4144.
[18] All AIRMET, SIGMET and METAR times are UTC, i.e. local time less one hour.

ENOR NORWAY FIR MOD ICE FCST WI N5700 E00730 - N5700 E00500 - N5945 E00030 - N6300 E00045 - N6300 E00400 - N6200 E00500 - N6200 E00730 - N5700 E00730 FL035/200 MOV E NC

Two SIGMET advisories had also been issued relating to turbulence on the route:

WSNO32 ENMI 140641

ENSV SIGMET B02 VALID 140645/141045 ENVV-

ENOR NORWAY FIR OCNL SEV TURB FCST WI N6100 E00730 - N6100 E00500 - N6200 E00500 - N6200 E00730 - N6100 E00730 SFC/FL100 STNR WKN

WSNO34 ENMI 140641

ENBD SIGMET C02 VALID 140645/141045 ENVV-

ENOR NORWAY FIR OCNL SEV TURB FCST WI N6200 E00730 - N6200 E00500 - N6300 E00730 - N6200 E00730 SFC/FL100 STNR WKN

The following weather observations were made around the time of take-off from Bergen Airport Flesland:

ENBR 140650Z 15019KT 9000 RA FEW008 BKN015 07/06 Q1015 TEMPO 4000 RA BKN008 RMK WIND 1200FT 15034G47KT=

ENBR 140720Z 15017KT 9000 -RA FEW008 BKN016 07/06 Q1015 TEMPO 4000 RA BKN008 RMK WIND 1200FT 15032G45KT=

The following weather observations were made at Ålesund Airport Vigra around the time of the landing there:

ENAL 140720Z 20012KT 9999 -RA BKN042 10/06 Q1007=

ENAL 140750Z 20012KT 170V230 9999 -DZ FEW021 BKN047 10/06 Q1007=

The weather report is available in its entirety in Appendix B.

1.8 Aids to navigation

Not relevant

1.9 Communications

1.9.1 About ten minutes after take-off from Bergen, SAS4144 established routine radio communication with Norway Control. SAS4144 maintained this communication with Norway Control during the icing incident. The AIBN has been given access to recordings of the radio correspondence.

1.9.2 Immediately after radio communication was established, SAS4144 was granted clearance to climb to FL190 and start the approach to Ålesund/Vigra via TUMIM3R. TUMIM3R is a standard instrument approach to runway 24 at Ålesund/Vigra. The approach starts at the TUMIM navigation point, located about 8 NM south-west of Sandane/Anda.

1.9.3 When the crew SAS4144 found it difficult to continue the climb, they reported icing problems and requested clearance to descend to FL150 (see Section 1.1.2.11). Norway Control granted clearance. Three minutes later, SAS4144 reported continued icing and requested turning towards the coast (see Section 1.1.2.12). The following exchange took place between SAS4144 and Norway Control from 08:09:17 hours to 08:10:04 hours:

08:09:17	SAS4144	We're still experiencing some moderate icing here, can we turn more left, more westerly course
08:09:27	Norway	Scandinavian four one four four that is approved, would you like to do the STAR for zero seven and maybe circling for two five, I can check with Vigra
08:09:38	SAS4144	Eh, say again please
08:09:40	Norway	Scandinavian four one four four you can turn away more north-westerly heading, would you like to do the STAR for zero six instead of two four
08:09:50	SAS4144	Eh, yea, we haven't checked the weather yet, but we might like to do that yes
08:10:04	SAS4144	We turn now to heading three three zero, Scandinavian four one four four

1.9.4 When the crew started to regain control of the aircraft after the stall, SAS4144 requested permission to descend (see Section 1.1.2.21). Norway Control then granted block clearance for all altitudes between FL100 and FL150. SAS4144 responded that they were descending towards FL100.

1.9.5 Seven minutes later, SAS4144 reported that they had experienced severe icing at FL150 above Bringeland. Norway Control passed on the information, and the weather service changed the SIGMET from MOD ICE to SEV ICE.

1.10 Aerodrome information

Not relevant

1.11 Flight recorders

1.11.1 <u>Cockpit Voice Recorder – CVR</u>

1.11.1.1 OY-JZC was equipped with a L3 Aviation Products FA2100 SSCVR cockpit voice recorder with a storage capacity of 120 minutes. After this, the data are automatically recorded over, unless the unit is de-energized. No recordings from the aircraft voice recorder were recovered from this incident. Thus, the AIBN has not had access to recordings of the communication between the crew, or other sounds in the cockpit.

1.11.2 <u>Flight Data Recorder – FDR</u>

1.11.2.1 OY-JZC was equipped with a L3 Aviation Products FA2100 SSFDR digital flight data recorder with a storage capacity of 50 flying hours. It contained data from the incident, which were retrieved and used in this investigation. The AIBN also retrieved data from the Flight Data Acquisition Unit memory card (FDAU).

1.11.2.2 The AIBN has used data from the flight data recorder to establish the course of events. The flight data recorder contained a number of parameters that were useful to this investigation. The French accident investigation authority (BEA) and the manufacturer (ATR) have also prepared their own analyses based on the data from the flight data recorder. These analyses have also made important contributions to help understand the course of events.

1.11.2.3 The flight data recorder parameters also include registrations of the direction of pitch movement and pitch forces applied to each of the control wheels. According to these data, the first officer tried to push the control wheel forward when the stick shaker activated. At the same time, the commander pulled it back, with an even greater force. This occasionally caused upward elevator deflection, i.e. nose up.

1.11.2.4 The ATR and BEA analyses have also established that the stick pusher activated twice. The ATR analysis indicates that both times the stick pusher met counter forces from the commander's control wheel. According to ATR, these data correlate to data in other known cases where someone has tried to "fight the pusher".

1.11.3 Quick Access Recorder – QAR

1.11.3.1 The aircraft was also equipped with a Quick Access Recorder used for flight operations and technical analyses (Flight Data Monitoring – FDM)[19].

1.11.3.2 Based on data from QAR, the AIBN prepared an animation to illustrate the critical sequence of the course of events. The animation is available on the AIBN website: www.nsia.no.

1.12 Wreckage and impact information

Not relevant

1.13 Medical information

Not relevant

1.14 Fire

Not relevant

1.15 Survival aspects

Not relevant

1.16 Tests and research

None

[19] DAR data was also downloaded from the PCMCIA card. This gave useful APM data such as lift and drag.

1.17 Organizational and management information

1.17.1 Jet Time AS

1.17.1.1 *The company*

Jet Time AS was established in 2006. The company has its headquarters in Copenhagen. Its principal activity is charter flights as well as various ad hoc operations, such as wet lease. In 2016, Jet Time AS had a fleet of ATR 72-500/600 (13 aircraft) and Boeing 737.

The company started operations for SAS on Norwegian domestic routes in June 2014. These operations continued until the end of January 2017. After this, Jet Time AS discontinued its operations with ATR 72-500/600. The company's last flight with ATR 72-500/600 was in September 2017.

As of February 2020, Jet Time AS only operated Boeing 737-700/800 (11 aircraft).

On 21 July 2020 Jet Time issued a press release announcing that the company was filing a bankruptcy petition due to cancelled charter contracts following the Covid-19 pandemic.

1.17.1.2 *The company's Operations Manual Part A (OM-A)*

The crew had access to the Jettime Operations Manual Part A – DK, Revision 20, from 2 September 2016. The manual includes general provisions about operations in icing conditions. It is primarily a description of procedures related to de-icing on the ground, but it also included guidelines on how the crew should act if they encounter icing situations. We draw particular attention to section gg) of Chapter 1.4 relating to the authority, duties and responsibilities of the commander.

> **gg)** shall, if icing exceeds the intensity of icing for which the aircraft is certified or if an aircraft not certified for flight in known icing conditions encounters icing, exit the icing conditions without delay, by a change of level and/or route, if necessary by declaring an emergency to ATC;

Figure 8: Section in Jettime Operations Manual Part A

Furthermore, section 8.3.8.2.4.4. of the manual contained the following general guidelines on the use of icing protection systems when aircraft enter areas of suspected icing:

> **8.3.8.2.4.4 Penetrating Areas of Suspected Icing Conditions**
>
> In general all ice-protection systems should be operated when ice is encountered or before entering an area in which ice is expected. Descents shall be planned so as to pass through known icing zones as quickly as possible.

Figure 9: Section in Jettime Operations Manual Part A

1.17.1.3 *The company's Operations Manual Part B (OM-B) ATR*

The crew had access to the Jettime Operations Manual Part B ATR 42/72, Revision 3, from 28 October 2014. Chapter 0 "General Information and Units of Measurement" states that the manual applies specifically to ATR 72, and that it contains additional information and instructions relating to technical, procedure and performance characteristics for this aircraft model.

Section 1.1.3 "Approved Types of Operation" in Chapter 1 "Limitations", lists, among other approved operations, flying in icing conditions.

1.1.3 APPROVED TYPES OF OPERATION

The ATR 72 is approved for the following kinds of flight and operation, both day and night, when the required equipment is installed and approved:

- Visual (VFR);
- Instrument (IFR);
- Icing conditions;
- Reverse thrust taxi (single or twin engine)

Figure 10: Section in Jettime Operations Manual Part B

Section 2.3.8 states that if the aircraft enters an area with visible humidity, the Total Air Temperature[20] (TAT) must be called out, and the crew must decide whether anti-icing equipment should be used. During climbs in visible humidity, the TAT must be monitored continuously.

As far as the AIBN can see, OM-B did not contain any operational requirements or changes in addition to the aircraft model’s QRH, AFM or FCOM that are of particular importance to this investigation.

1.17.1.4 *Company program for Upset Prevention and Recovery Training (UPRT)*

Jet Time AS' Operations Proficiency Check – OPC-D for autumn 2016 comprised two main parts: training session (Training Day) and standard session (OPC Day).

The Training Day took place at the ATR Training Centre in Toulouse or at CAE's premises in Amsterdam. The core of the training session consisted of four hours of Upset Prevention and Recovery Training in a flight simulator. Prior to the first simulator session, the participants first had to complete a theoretical computer-based training course (CBT). The training also comprised 1.5 hours of briefing before, and a one-hour debriefing after, the simulator session.

The OPC Day included "Line Oriented Flight Training" (LOFT) with flying on the Oslo – Billund route.

1.17.1.5 *The company's safety management system (SMS) and analysis of new routes*

In its investigation report following an icing incident involving an ATR 42-320 over Folgefonna Glacier, SL 2009/02[21], the AIBN argued that the flight safety program, which at the time was a requirement in JAR-OPS 1.037, should include safety analyses of new routes, and issued a safety recommendation in this regard. In 2012, the flight safety

[20] The Total Air Temperature (TAT) is the true outside temperature, plus any temperature rise due to compressibility.
[21] The Accident Investigation Board Norway (AIBN), SL 2009/02: *"Report on the serious incident over glacier Folgefonna, Norway on 14 September 2005 with ATR 42-320, LN-FAO, operated by Coast Air AS."*

program was replaced by a requirement to establish a safety management system with an implementation deadline of 28 October 2014 in Norway. One of the requirements of Regulation (EU) 965/2012 states that operators must identify any safety hazards, evaluate such hazards and handle any risks associated with them, including mitigating measures to reduce the risk and verify the effect of the measures[22].

Jet Time AS had performed a safety analysis of its operations in Norway as part of the company's safety management system. Measures included selecting the right pilots who would operate routes in Norway to handle challenges related to such operations. As far as the AIBN can see, however, the analysis did not include any special assessments of, or focus on, the aircraft's suitability for Norwegian icing conditions.

1.17.1.6 *Company experiences with operating scheduled flights with the ATR 72-212A model in Norway*

From the time Jet Time AS started operations with the ATR 72 in Norway in June 2014 and until the incident involving SAS4144, the company had not had any similar incidents.

1.17.2 SAS

1.17.2.1 SAS and Jet Time AS entered into a wet lease agreement in 2011. SAS4144 was operated pursuant to "Amendment 3 (ATR 72-600)" of 22 September 2015, which was a supplement to the applicable agreement of 3 May 2013.

1.17.2.2 When asked by the AIBN, SAS stated that there were no special restrictions related to operations in Norway beyond regulatory authorizations and IOSA registration.[23] Moreover, SAS did not react to Jet Time AS' lack of special focus on the aircraft type's suitability for operations in Norwegian winter and icing conditions with regard to the routes they would operate on behalf of SAS.

1.17.2.3 However, SAS conducted its own audits of Jet Time AS. Furthermore, pursuant to the wet lease agreement, Jet Time AS was required to submit all relevant safety data to SAS Safety Office. This included e.g. reports relating to accidents or serious aircraft incidents, as well as significant occurrence or safety reports.

1.17.2.4 SAS has stated that until the incident occurred, they had had no indications of any problems with Jet Time AS' operations in Norway.

1.17.3 Regulatory oversight and cooperation

1.17.3.1 Jet Time AS' AOC and associated Operations Specifications were issued by the Danish Transport, Construction and Housing Authority, who also conducted operator inspections. During the period from the company started its operations in Norway in June 2014 and until the incident occurred in November 2016, the Danish Transport, Construction and Housing Authority conducted eight "flight inspections" of the company, four of which took place on the ATR operations. In addition, 12 "function inspections" were conducted in the same period.

[22] EASA Part ORO.GEN.200(a)(1)
[23] IOSA is an abbreviation for IATA Operational Safety Audit. Members of the airlines' trade association IATA (International Air Transport Association) must be registered in the IOSA register. This entails that they are subject to inspections of the flight operations management and control systems.

1.17.3.2 SAS was subject to regulatory oversight by the three Scandinavian aviation authorities, who had also approved the wet lease agreements. This means that, although only the Danish Transport, Construction and Housing Authority had a regulatory enforcement mandate regarding Jet Time AS, the Swedish Transport Agency and the Civil Aviation Authority Norway both had the opportunity to form an opinion about the safety aspects of the planned operations in Norway.

1.17.3.3 It seems the three authorities were not concerned about whether Jet Time AS, as part of their safety management system, conducted its own safety analysis of the routes they would operate on behalf of SAS.

1.17.3.4 Furthermore, there seems to have been no communication or exchange of information between the three regulatory authorities with regard to Jet Time AS' operations in Norway.

1.18 Additional information

1.18.1 The crew's knowledge about the conditions along the route and assessment of the relevant flight

1.18.1.1 Both crewmembers had flown the Bergen – Ålesund route several times previously, also during icing conditions. They were familiar with how moist, hot air that comes in over the coast of Western Norway due to weather fronts, tends to rise due to higher terrain inland, thus causing icing.

1.18.1.2 They were prepared for icing on this flight and agreed to take a more westerly course and descend to a lower altitude, if the icing became too intense. The commander has e.g. explained that he was pleased they could take off in a southward direction with a right turn (westwards) out over the sea. After the incident, the crew stated that it might have been better had the flight stayed on a more westerly track throughout the flight.

1.18.2 Risk of loss of transfer of knowledge about icing conditions in Norway

1.18.2.1 In its investigation report following an icing incident involving an ATR 42-320 over Folgefonna Glacier, the AIBN wrote the following in Section 2.3.1.3 of report SL 2009/02[24]:

> *The AIBN believes that the introduction of joint European requirements and American textbooks in basic training in aviation meteorology may lead to pilots missing out on important knowledge of specific Norwegian conditions. Operators of propeller aircraft in the western part of Norway, and between the western and the eastern part of Norway, should devote special attention to subjects such as meteorology, aerodynamic effect and reduction of the aircraft's performance in icing.*

1.18.2.2 This view was based on the following reference:

> *Previously, the textbook Flymeteorologi [Aviation meteorology] was used at Norwegian flying schools (Dannevig, P. 1969). This textbook is no longer*

[24] The Accident Investigation Board Norway (AIBN), SL 2009/02: *"Report on the serious incident over glacier Folgefonna, Norway on 14 September 2005 with ATR 42-320, LN-FAO, operated by Coast Air AS."*

available. Today's textbooks on ATPL theory are usually in English and not as *comprehensive as the book by Dannevig. The Flymeteorologi book was written for Norwegian pilots and deals with Norwegian flying conditions which are often associated with more extreme winter conditions than might be encountered in other countries. This book has a chapter called "Isingsforholdene langs vanlige flyruter" [Icing conditions along common air routes] in which the Folgefonna glacier is mentioned. The following text is taken from the book:*

… Map showing precipitation in Norway shows a strong increase from the coast towards the mountain slopes, but then a decrease towards the central mountainous part. We find this maximal zone as far north as in Troms, but it is particularly noticeable between Vestfjorden and Fosna and from Stadlandet to Rogaland. The distance from the coast may be 25 to 50 km, varying somewhat with the terrain conditions. Here annual precipitation can regularly be up to double, even triple in some places, of what we get along the coastline. This is given visual expression in the major glaciers, which often reflect favourable terrain conditions for precipitation. There is no direct link between icing and volume of precipitation. However, the process resulting in precipitation will also at a certain stage lead to icing. Where the clouds have been activated, they will be richer in supercooled water. Many cases where icing led to difficulties are known from the region from the Bodø area to Namdalseid, close to Stadlandet and around Folgefonna …

… On the windward sides of mountains, stationary icing zones can be quite extensive. Ice can form at the same height over a longer time; the intensity is usually light to moderate. However, when warm, unstable air rises, it can release large volumes of water and lead to severe icing.
It can be particularly bad if an active cloud system intensifies towards a mountain. In this type of situation – which normally also results in heavy precipitation – a mixture of clear ice and rime ice might occur at a certain stage, often with a light elements of snow which becomes attached.
This sticky mixture can accrete [on the airframe][25] very quickly even if the temperature is fairly low. In this situation, very difficult conditions may be experienced. It will be particularly bad if the cloud system is orientated along the mountain and the flight is also moving in this direction. It will often be possible to avoid the worst areas by heading out over the sea or by maintaining a level of more than double the height of the mountain. However, the safest way is obviously to fly on the leeward side …

1.18.2.3 Dannevig wrote the following on how to select flight level in maritime hot air masses:

In unstable hot air masses, it does rarely pay off to fly at so-called "mean" flight levels. The most severe turbulence, greatest risk of lightning and icing are, at our latitudes, often encountered at altitudes above 3000 m, in very hot air above 4-5000 m. … Icing in hot air most often occurs at relatively high altitudes or near the ground. In the higher strata, icing is sometimes observed in both summer and winter, when clouds are formed above freezing level, due to instability or orographic lift towards mountain ranges. Above the sea and low terrain, it is often easy to avoid this icing by flying low.

[25] AIBN note.

1.18.3 ATR in-service experience

1.18.3.1 *The Roselawn accident and icing certification of turboprop aircraft*

On 31 October 1994, an accident occurred near Roselawn, Indiana, USA involving an ATR 72-212 (N401AM). The crew lost control of the aircraft in icing conditions. 68 people were killed in the accident. The accident investigation showed that supercooled large water droplets (SLD)[26] could flow backwards along the top of the wing's leading edge before freezing and attaching to the surface behind the pneumatic de-icing boot (see Section 1.6.7). The NTSB report[27] concluded that ice ridges formed on top of the wing, behind the de-icing boot as a result. This could not be removed by the aircraft's de-icing systems. The use of flaps while the aircraft circled in a holding position was considered to have contributed to ice forming on the top of the wing.

The NTSB report has had a major impact on the aviation industry's subsequent understanding of icing and on the certification of propeller operated aircraft for operation in icing conditions in general. It has been particularly important for understanding the so-called "runback" effect of freezing drizzle (SLD) and the importance of better protection. The aviation industry had not previously been sufficiently aware of this.

Until 2015, the European type certification specifications relating to droplet size (diameter) in connection with certification for flight in icing conditions was 50 μm. ATR 42/72 is type certified in accordance with these regulations (JAR 25, Ch. 13).

In 2015, EASA published Amendment 16 to the type certification specification, CS 25 "*Large Aeroplanes*" with new and more comprehensive requirements for certification related to flight in icing conditions: CS 25.1420 with Appendix O. These new requirements covers both freezing drizzle and freezing rain. One of the requirements is that the aeroplane, following detection, must be capable to operate safely while exiting all icing conditions.

The amended certification specifications are not retroactive, and thus only applicable for certification of new aeroplane types.

1.18.3.2 *Aileron hinge moment reversal*

In its investigation of the Roselawn accident, the NTSB found that the ice deposits that had formed behind the de-icing boots and in front of the aircraft's aileron most likely created aerodynamic effects which caused aileron hinge moment reversal. NTSB concluded that American Eagle flight 4184 suddenly rolled over on its back, control was lost and the aircraft crashed as a result of aileron hinge moment reversal. The roll took the crew, who had engaged the autopilot, by surprise.

Later versions of ATR 42/72 were specifically modified to improve roll stability in icing conditions. These modifications are described in Section 1.6.3. Several other improvements have also been made to make the ATR 42/72 models less sensitive to

[26] Supercooled Large Droplets (SLD) are defined as supercooled water droplets (freezing drizzle) with a diameter of 200 – 500 μm.
[27] NTSB/AAR-96/01: *In Flight Icing Encounter and Loss of Control Simmons Airlines d.b.a. American Eagle Flight 4184 Avions de Transport Regional (ATR) Model 72-212, N401AM Roselawn, Indiana October 31, 1994*

icing. The anti-icing systems on OY-JZC are described in more detail in Section 1.6.3 to 1.6.8, whereas the procedures are described in Section 1.6.9.

Just like the newer versions of ATR 42/72, OY-JZC was modified to prevent aileron hinge moment reversal and improve banking stability in icing conditions and in the event of stalling. This is described in Section 1.6.3.

Moreover, the procedure for stall recovery, or in the event of abnormal roll control, contains a separate memory item stating that if the flaps are not already down, FLAPS 15 must be extended (see Section 1.6.11.4). Moreover, the checklist for severe icing contains an item stating that FLAPS 15 must be extended if the pilot experiences an unusual roll response or uncommanded roll control movement is observed (see Section 1.6.11.3).

Experiences from the Roselawn accident have shown that such, and other, indications that the aircraft is about to lose control, may be masked by the autopilot. Consequently, it was afterwards emphasized in the severe icing procedure that the autopilot had to be disengaged (see Section 1.6.11.3).

1.18.3.3 *Questions to the crew on SAS4144 concerning aileron hinge moment reversal and the use of flaps*

The first officer, who was PF, was asked about the forces in the control wheel in connection with the wing drops. Except for her finding it unusually difficult to push the control wheel forward (see Section 1.1.2.14), she did not at any time notice forces trying to move the control wheel "the wrong way", i.e. in the same direction of the wing drop.

Both crew members have explained that they knew the checklist for severe icing contained a memory item stating that flaps 15° must be extended if unusual banking responses or uncommanded control wheel deflections occur.

Flaps 15° is a memory item on the checklist for stall recovery. According to the crew, the control loss happened so suddenly that they did not have time to extend the flaps before it was over. Nor did they increase engine power from CRZ to MCT, as stated in the checklist.

1.18.3.4 *Previous icing-related incidents in Norway*

In Norway, a serious aircraft incident with an ATR 42-320 occurred over Folgefonna Glacier in 2005, where the crew lost control of the aircraft in icing conditions. According to AIBN report (SL 2009/02)[28], the lateral instability the aircraft experienced, may have been caused by aileron hinge moment reversal. The AIBN has also investigated an additional icing-related incident with an ATR 42-300 in Bergen in 2007 (AIBN report SL 2013/03)[29].

1.18.3.5 *Three icing incidents with the ATR 72-212A model*

On 21 December 2016, a serious incident occurred involving a British ATR 72-212A (G-COBO) en route from Guernsey to Manchester. The crew lost control of the aircraft in

[28] The Accident Investigation Board Norway (AIBN), SL 2009/02: *"Report on the serious incident over glacier Folgefonna, Norway on 14 September 2005 with ATR 42-320, LN-FAO, operated by Coast Air AS."*
[29] The Accident Investigation Board Norway (AIBN), SL 2013/03: *Report on serious incident at Bergen Airport 9 November 2007 with an ATR 42-300, OY-JRY.*

severe icing. The incident was investigated, and a report was issued by the British Air Accidents Investigation Branch (AAIB)[30].

On 9 September 2017, a serious incident occurred to a Spanish ATR 72-212A (EC-KKQ) en route from Alicante to Madrid. The crew lost control of the aircraft during severe icing. The incident was investigated, and a report was issued by the Spanish Civil Aviation Accidents and Incidents Investigation Commission (CIAIAC)[31].

There are a number of similarities between the two incidents above and the incident involving OY JZC.

- Prior to losing control of the aircraft, the crew had tried to climb out of the icing conditions.
- The aircraft autopilot was engaged in severe icing conditions.
- The airspeed dropped to below Vmin-ops + 10 kt.
- The aircraft went into a combination of large uncontrolled banking excursions and pitching oscillations.
- The commander of EC-KKQ also initially reacted by pulling the control wheel back when the stick pusher activated.

The three aircraft all had the same upgraded icing protection system (see Section 1.6.3 – Section 1.6.8).

1.18.4 Parallel flights – SAS4144 and WIF564

1.18.4.1 At 0744 hours, five minutes before SAS4144, Widerøe flight WIF564 took off from Bergen Airport Flesland heading for Kristiansund. The aircraft, a Bombardier Aerospace DHC-8-103, also took off in a southerly direction, but unlike SAS4144, it took an eastward turn. This means WIF564 followed a slightly more easterly route than SAS4144, but essentially the two aircraft followed the same route north. The figure below shows the two aircraft tracks.

[30] AAIB Bulletin 12/2017 – G-COBO – EW/G2016/12/08
[31] CIAIAC Report IN-020/2017, of 27 November 2019

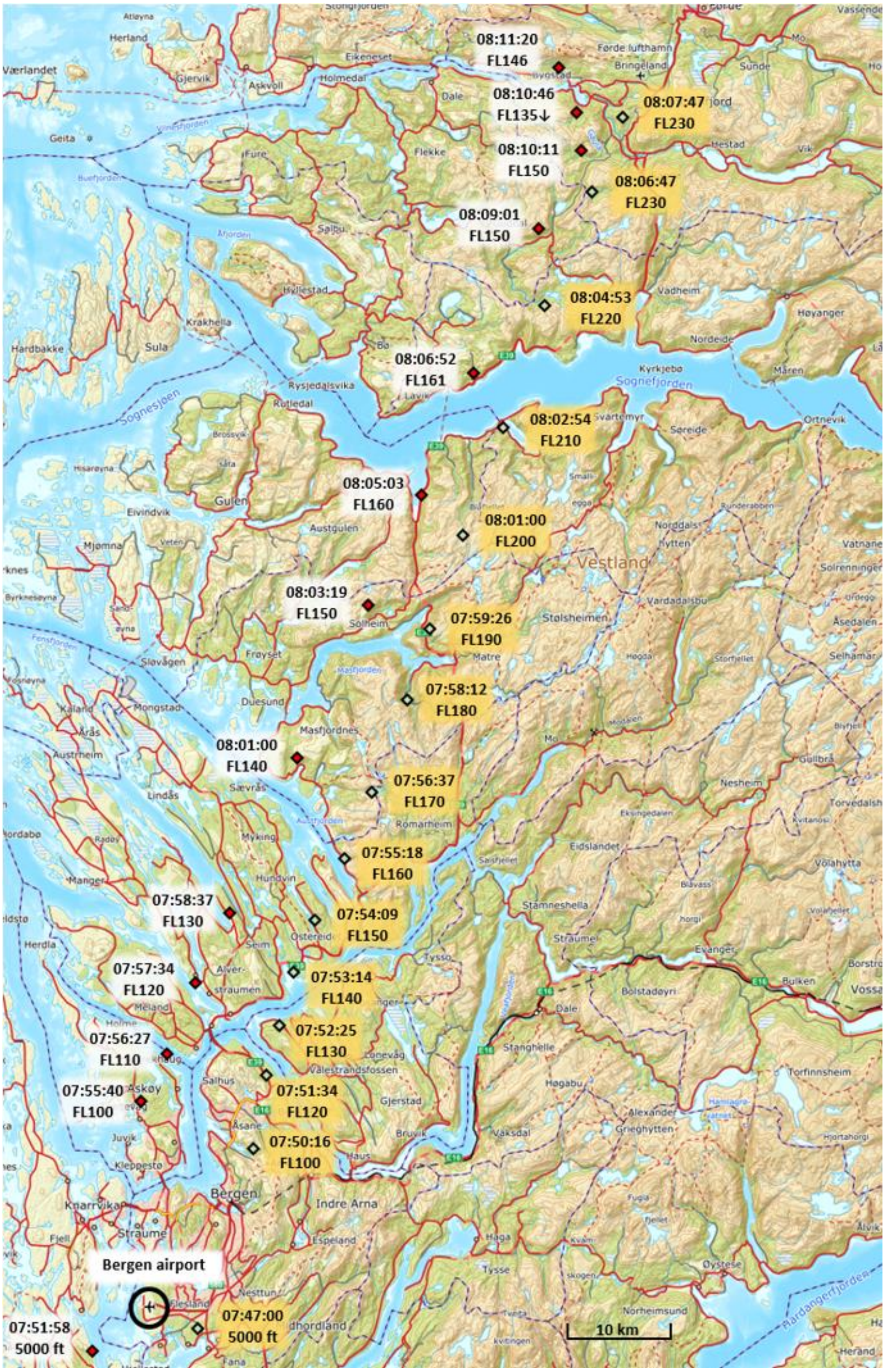

Figure 11: Comparison of the SAS4144 track (red dots and white text boxes) and WIF564 (yellow dots and text boxes) after departure from Bergen Airport Flesland. Illustration based on radar data from Avinor. Illustration: AIBN

1.18.4.2 After climbing for about 25 minutes, WIF564 was established at its cruise altitude FL230. The commander of WIF564 has stated that *"icing was not of a particularly noticeable nature"* and that the flight took place at the planned flight level (FL).

1.18.4.3 Based on radar data from Avinor, the AIBN has also estimated the two aircraft's ascent or climb profiles. The graphs below show the aircraft flight levels in relation to the number of minutes since take-off from Flesland.

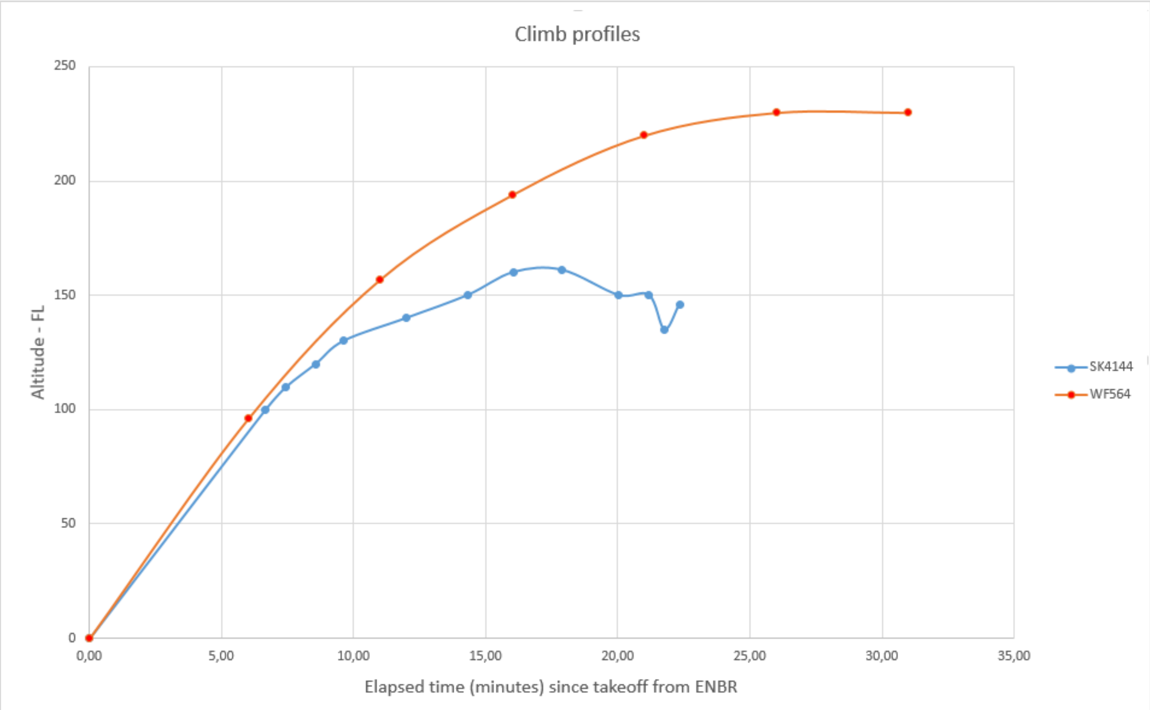

Figure 12: Comparison of SAS4144 and WIF564 climb profiles during the climb after take-off from Flesland. Note that WIF564 took off five minutes before SAS4144 and followed a slightly more easterly track than SAS4144. Illustration: AIBN

1.18.4.4 In their comments to the draft version of this report, BEA has made the following remarks:

> *This comparison may be misleading. We do not know the weight of the other turboprop. In addition, it is not demonstrated that both aircraft did fly in the same air mass and encounter the same icing conditions. On the other hand, it has to be noted that the DH8 had already reached FL 200 when he flew in the area where the ATR encountered severe icing conditions. This difference in climbing performance may have contributed to increase the time of exposure of the ATR.*
>
> *It is difficult to conclude, only using the degradation of inflight climbing performances during these two flights on the vulnerability of one aircraft or another in regards to icing sensibility.*

1.18.5 <u>Startle effect – reactions to sudden or unexpected situations</u>

1.18.5.1 On 12 February 2009, Colgan Air Connection flight 3407 was approaching Buffalo, New York during icing conditions, when the aircraft lost control, stalled and crashed into a home on the ground. Everybody on board the aircraft (45 passengers and 4 crewmembers) as well as a person in the house, lost their lives in the accident.

1.18.5.2 The aircraft, a Bombardier DHC-8-400 (Q400) was flying at an altitude of 2,300 ft when the airspeed decreased so much that the stick shaker was activated, and the autopilot disconnected. When the stick shaker activated, the commander, who was PF, immediately reacted by pulling the control wheel toward him instead of pushing it forward to reduce the angle of attack and thus prevent stalling. According to the accident report [32] issued by the US National Transportation Safety Board (NTSB), the commander's reaction made the situation worse.

1.18.5.3 Furthermore, the NTSB wrote in its report that the commander's reaction on the stick shaker did not correspond with the training that he had received but was more in line with a reaction caused by surprise and confusion.

1.18.5.4 This and other accidents where crew members have reacted incorrectly following sudden and unexpected situations in the air, has increased the industry's focus on the startle effect or startle response phenomenon. This, in turn, has resulted in research and proposals for training programs to teach aircraft crews to reduce or overcome the startle effect, both individually and as a team. One example is the EASA research report *Startle Effect Management*, published in the autumn of 2018. The report, prepared by the Netherlands Aerospace Centre (NLR), is based on a research project financed by the EASA. The project resulted in the development of a new recommended technique and training program aimed at counteracting the startle effect.

1.19 Useful or effective investigation techniques

No methods warranting special mention have been used in this investigation.

2. ANALYSIS

2.1 Introduction

2.1.1 For a brief period, the SAS4144 crew lost control of the aircraft in severe icing conditions. A factor common for many incidents where the crew have experienced control problems, or lost control of the aircraft in icing, be it the ATR 42/72 or other aircraft models, is that the crew have lacked situational awareness. They have not detected the gradual performance degradation and have not taken sufficient precautions in time.

2.1.2 In this case, the crew were aware that moderate icing was forecast, and were prepared for this. They activated the aircraft's icing protection systems and paid attention to ice accretion on the aircraft. Furthermore, it seems the crew, on the whole, understood the situation when icing became too severe for the aircraft systems to prevent ice from accumulating on the aircraft, and they were leaving the area. Despite this, the crew lost control of the aircraft for a brief period. In this analysis, the AIBN will look into how this could have happened. The course of events analysis is divided into three phases:

- Flight preparations
- The flight up to loss of control
- Loss of control

[32] NTSB/AAR-10/01: *Loss of Control on Approach Colgan Air, Inc. Operating as Continental Connection Flight 3407 Bombardier DHC-8-400, N200WQ Clarence Center, New York February 12, 2009*

As well as analysing these three phases, the AIBN will discuss aspects of the flight crew cooperation and training relevant for the occurrence. We will also look into whether other factors, such as the wet lease, winter operations involving a foreign operator in Norway and authority inspections, may have had an impact on the course of events. Finally, we will discuss operations with ATR in Norway during the icing season.

2.2 Flight preparations

2.2.1 The crew planned to follow a common flight path on their flight from Bergen to Ålesund. They were aware that moderate icing had been forecast and were consequently prepared to divert westward and towards the coast if the icing should become too severe.

2.2.2 After the incident, the crew stated that they should have chosen a more westerly track from the outset. The AIBN agrees that a different route could have been advantageous in terms of potentially lower precipitation and icing intensity.

2.2.3 Furthermore, the AIBN believes that the choice of flight level might be a learning point. The temperature profile for Bergen (ENBR) indicates that moderate icing could be expected from FL80 up to FL160, whereas the icing area was higher up further north towards Bringelandsåsen (ENBL), where moderate icing could be expected up to FL200[33]. Even though the aircraft is certified for flight in icing conditions, the planned flying altitude, FL190, may not have been the most prudent choice in terms of avoiding prolonged exposure to icing conditions.

2.2.4 Both crewmembers have stated to the AIBN that they hoped to climb above the clouds and thus above the icing conditions. They seem to have believed that the icing would decrease once they climbed above FL130 – 140. The crew seem to have been surprised that this did not happen and that icing in fact increased the higher they climbed. The AIBN interprets this as an indication that the crew had not acquired sufficient knowledge about how high up icing would occur when they prepared for the flight.

2.2.5 The AIBN understands that pilots would prefer to climb above icing conditions when possible. This would have taken the aircraft out of the icing as well as giving a better altitude margin for terrain clearance than if the aircraft were flown below the icing conditions. SAS4144 had, for example, more than 7,600 ft clearance to the ground at the lowest point during the aircraft loss of control. This, in itself, is reassuring. However, there was icing at much higher altitudes, and it increased in intensity from FL100 and up. Which is to be expected when maritime hot air rises towards the terrain.

2.2.6 Another factor when choosing flight level is that, in general, an aircraft is exposed to more icing when it is climbing and thus operating with an increased angle of attack. This entails that the higher the aircraft climbs, the longer it is exposed.

2.2.7 If, during their pre-flight preparations, the SAS4144 crew had gathered and used all the available information about how high up icing conditions could prevail along the entire route, it may well be that they would have chosen a different flight level at the outset. Moreover, it is unlikely that they would have attempted to climb above the clouds when the aircraft encountered severe icing and the climb speed decreased, if they had known that they would need to climb another 6000 ft or more.

[33] See temperature profiles for ENBL and ENBR respectively in the weather report included in Appendix B

2.2.8 The AIBN is of the opinion that the concern expressed in report SL 2009/02 is still relevant. This applies to Norwegian as well as foreign pilots.

2.3 The flight prior to loss of control

2.3.1 The departure from Bergen and the flight until SAS4144 reached FL100 passed without incident. The crew quickly (within five seconds) activated the pneumatic de-icing system when the ice detector warned of ice accretion on the aircraft. It is not clear whether they had any visually observations of ice accretion before the ice detector warning light illuminated. The FCOM procedure requires activation of the de-icing equipment at the first indication of ice accretion, not waiting for the detection by the ice detector.

2.3.2 Over the next four minutes, the crew got several indications that the icing was developing into a problem. Ice continued to form, and the climb speed dropped gradually. Then, after one and two minutes respectively, the crew got two clear indications that the aircraft had encountered severe icing and that the icing intensity surpassed the capacity of the aircraft ice protection systems. These indications were performance degradation (decreased climb rate and speed) eventually causing the APM alert *Degraded perf.* to display at FL137, and the streaks of water/ice along the window at FL140 (see "Detection" in the severe icing checklist, item 1.6.11.3). According to all procedures and checklists, the aircraft should immediately have left the area at this time.

2.3.3 When the crew increased PWR MGT to MCT and reduced the airspeed to 165 kt, the climb speed increased temporarily. However, it dropped relatively quickly although the aircraft to a certain degree continued to climb. It was not until the aircraft reached FL160 and the APM alert *Increase speed* was displayed, that the crew increased the speed back to 170 kt and requested clearance to descend to FL150. In the meantime, it became necessary to use the three checklists *Severe Icing, Degraded Performance*, *Increase Speed*, one after the other. One item in all the checklists is "IAS above ICING BUG + 10 kt", i.e. the speed should not drop below 166 kt. The AIBN believes that in general the airspeed was slightly low throughout the climb, and that this may have resulted in increased ice accretion on the aircraft[34].

2.3.4 Descending to FL150, the crew reduced PWR MGT to CRZ. Engine power was not increased again after the aircraft levelled off at FL150. That may have contributed to the speed dropping more rapidly. According to the severe icing checklist, PWR MGT must be in MCT (1.6.11.3).

2.3.5 In the AIBN's opinion, it was particularly unfortunate to use the autopilot in altitude hold mode when SAS4144 levelled off at FL150 and the aircraft was still experiencing icing. Regardless of aircraft model, it is easy in such conditions to find oneself in a situation where the autopilot gradually and imperceptibly increases the angle of attack in order to compensate for the loss of lift caused by reduced lifting capacity and increased drag as ice builds up on the aircraft[35]. This, in turn, will expose the aircraft to further icing, which can lead to a vicious circle ending in the aircraft stalling. When asked what they would have done differently, both pilots said they waited too long before disengaging the

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[34] In general, low speeds increase the angle of attack, which in turns means that a larger front area is exposed to icing. This increases drag, causing the speed to drop. Hence, it is necessary to increase the angle of attack even more.
[35] This primarily applies to aircraft without an autopilot auto-throttle function, such as the ATR 42/72.

autopilot. ATR's manuals, procedures and checklists also did warn against the use of autopilot if an aircraft encounters severe icing.

2.3.6 Shortly after the aircraft had levelled off at FL150, the SAS4144 crew requested clearance to change the course due to icing and were granted such clearance by air traffic control. This clearance was given together with a question about whether the pilots wanted to change their approach to Ålesund. This led to a radio exchange between SAS4144 and Norway Control. The change of course towards the west was not initiated until after this exchange was terminated. 44 seconds elapsed from the time when SAS4144 requested to change course and before the actual change of course was initiated by the crew.

2.3.7 This resulted in unnecessary loss of time in an already tight time frame. No more than just over a minute passed from the time the aircraft levelled off at FL150 and until control was lost. In retrospect, it appears that it would have been better had the crew first initiated the change of course and then requested clearance. This would have been more in line with the old, but still current, task prioritization mantra for pilots: "*Aviate – Navigate – Communicate*".

2.3.8 SAS4144 had, in two calls, three minutes apart, indicated that they were experiencing problems due to icing. The AIBN has the impression that Norway Control understood the situation and was offering help, when they not only approved the change of course, but also offered an alternative approach to Ålesund. In stressful situations, an aircraft crew may not have capacity to consider more than what is ongoing in the present moment. Thus, the AIBN believes that one lesson air traffic control can draw from this is that they should have just given SAS4144 the clearance they requested, and then raised the issue of a changed approach after the change of course had been completed.

2.3.9 In addition to too much time passing from when SAS4144 encountered severe icing until the crew initiated the turn towards the west to escape the icing conditions, the situation was aggravated by the fact that the turn was performed using the autopilot heading function in high bank mode. The system caused the aircraft to bank at an angle of approx. 30 degrees, while the angle of attack continued to increase.

2.3.10 About five minutes passed from the first indications of icing until the aircraft encountered icing conditions that were too severe for the aircraft ice protection systems to handle. Ten minutes later the aircraft was out of control. In retrospect, it appears that the crew did not make optimal use of these ten minutes, as they tried to climb above the clouds and the ice. Should one try to understand the crew's priorities, it is important to remember that they expected, at any time, to clear the clouds and escape the icing conditions, after having climbed above FL140. The AIBN interprets the fact that they, after having abandoned this approach, temporarily levelled off at FL150 and failed to change the course immediately, as an indication that the crew still did not fully understand how serious the situation had in fact become. The same applies to the fact that the autopilot was not disengaged earlier.

2.4 Loss of control

2.4.1 Introduction

In addition to the AIBN's own analyses based on flight data recorder information and interviews with the crew, the following account of the loss of control is also based on flight data recorder analyses performed by the ATR and BEA.

2.4.2 Banking

2.4.2.1 The westward turn was initiated with the autopilot engaged. It kept the aircraft turning left at a banking angle of 30 degrees. It is not inconceivable that ice at that point could have accumulated unevenly and the autopilot compensated for this by deflecting the ailerons towards a right bank.

2.4.2.2 The airspeed dropped in the turn, and the angle of attack eventually increased so much that it reached the stick shaker limit. Activation of the stick shaker automatically disengaged the autopilot, which released the aileron deflections. Any aileron deflection towards a right bank thus disappeared. This could be one possible explanation of why the banking in the left turn suddenly increased sharply. Another possible explanation might be that the left wing dropped as a consequence of the wings being stalled, or close to stalling. That may also explain the subsequent sharp roll to the right. See also Section 2.4.4 about flaps.

2.4.2.3 The first officer responded quickly to the banking by pushing the control wheel forward, combined with aileron and rudder deflection in the opposite direction to bring the wings level. The AIBN has not been able to clearly determine whether or not these reactions improved the situation[36]. When asked about this, ATR emphasized that the most important response is to reduce the aircraft's angle of attack to escape or prevent stalling. The AIBN agrees with this.

2.4.2.4 Data from the flight data recorder from the incident contain both aileron deflection and corresponding forces on the control wheel. The AIBN has compared these data but did not find any indications of aileron hinge moment reversal. Nor did the crew indicate that there were any abnormal forces or banking deflection on the control wheels. The AIBN is therefore of the opinion that aileron hinge moment reversal was not a factor in this incident.

2.4.3 Stalling

2.4.3.1 Both the commander and the first officer reacted quickly when the stick shaker activated. The first officer tried to push the control wheel forward to reduce the angle of attack and thus prevent stalling. However, the commander pulled back and may have contributed to increasing the angle of attack, thus activating the stick pusher. The stick pusher activated twice, applying forward force on the control wheel. Both times, the commander held or tried to hold the pusher back against the combined forces from the first officer and the stick pusher.

[36] For some aircraft, use of the opposite aileron may aggravate the tendency for wing drop at high angles of attack. Instead, it is recommended to "pick up" a dropping wing by using the opposite rudder. However, the FCOM for OY-JCZ warned against using the side rudders to induce banking.

2.4.3.2 The commander's initial response is likely to have aggravated the situation and may have contributed to the first sharp roll to the left, as the angle of attack was not reduced quickly enough. The AIBN has not been able to determine whether the aircraft actually did experience an aerodynamic stall, or if the nose pitched down due to elevator inputs.

2.4.3.3 The situation is likely to have been highly stressful and confusing for the crew. The stick shaker suddenly activated and the autopilot disengaged, followed by a sudden and sharp increase in banking when they entered the turn, combined with the nose of the aircraft pitching down in relation to the horizon. An indication of this is that the pilots did not seem to have noticed that they were applying opposite forces on the control wheel, nor that the stick pusher activated twice in a row. Furthermore, two memory items on the checklist, Flaps 15° and PWR MGT to MCT, were omitted.

2.4.3.4 The AIBN finds it likely that the commander's initial response may have been a result of having been startled and surprised – a so-called startle effect. Fortunately, the incorrect reaction was of short duration and the commander subsequently helped regain control of the aircraft.

2.4.4 Flaps

2.4.4.1 Only a few aircraft types have extension of flaps as part of their stall recovery procedure. However, this may have a stabilizing effect on aircraft that lack sufficient lateral stability near the critical angle of attack, not unlike the effect of washout. Thus, extending the flaps may have contributed to recover from the stall (see Section 2.4.2).

2.5 Aspects of crew resource management and training

2.5.1 Crew resource management – CRM

2.5.1.1 In interviews, the crewmembers have independently of each other stated that they felt cooperation functioned well, both before, during and after loss of control. There is nothing to indicate that the crewmembers were not getting along, that there was disagreement between them, or that one was working against the other or was not contributing.

2.5.1.2 However, the AIBN believes that what took place immediately after the stick shaker activated must be characterized as a temporary breakdown of crew resource management – at a non-verbal level. The most obvious indication was that the first officer and the commander applied opposite forces on the control wheel without being aware of it, but also that two memory items on the checklist were disregarded. It appears that cooperation in fact broke down without the crew being aware of it.

2.5.1.3 In addition to the commander's initial response, probably as a result of the startle effect, the AIBN would like to draw attention to two other aspects that may have contributed to a non-optimal crew cooperation.

- There seems to have been no callouts[37] when the loss of control occurred. A callout that would have been appropriate when the stick shaker activated is *"STALL"* which means immediate implementation of the checklist *"Recovery After Stall or Abnormal*

[37] "Callout" is the term used when a crewmember calls out a standard phrase to make the other member aware of a condition/indication related to safety and that requires action or consideration.

Roll Control". If the commander had wanted to take over control when the incident occurred, it would be standard callout procedure to call *"MY CONTROLS"* and for the first officer to respond by calling *"YOUR CONTROLS"* before leaving control of the aircraft to him. This would have been to ensure that both crewmembers were clearly aware of who operated the aircraft.

Callouts are a way of establishing a common understanding of a situation, which also help ensure that the crew focus on the most urgent tasks at any given time. Timely callouts may also prevent a startle effect. Jet Time AS had standards for callouts, and these were included in both OM-A and OM-B. However, the AIBN did not find that the manuals covered the two cases mentioned above.

- In some situations, it may be necessary for one pilot to help the other operate the control wheels, if, for instance, the pilot flying finds the aircraft heavy on the controls. In such cases, the most appropriate approach is for the pilot who needs help to request such assistance and specify what aileron or rudder deflection he or she needs help with. In this instance, the commander's intervention was unfortunate.

  Another factor is that such intervention may make the task distribution between the PF and the PM less clear and cause misunderstandings as to who should do what, e.g. who should extend the flaps or increase engine power.

2.5.1.4 The breakdown of crew resource management on SAS4144 did not last long. The crew regained control of the aircraft and continued its flight to Ålesund where the aircraft was subsequently landed normally. The AIBN is of the opinion that this shows resilience[38] on behalf of the crew, also as a team. They managed to recollect themselves and gain control of the situation, thus averting an accident. The AIBN's report SL 2016/11[39] published after a serious aviation incident involving a Widerøe aircraft during approach to Svolvær in 2010, contains a separate section *"2.12 Why did it turn out well?"* that discusses this issue.

2.5.2 Simulator training and Upset Prevention and Recovery Training – UPRT

2.5.2.1 The AIBN believes it is hardly a coincident that the first officer, who had recently completed simulator training as part of the UPRT training, was the one to respond correctly when she tried to push the control wheel forward when the stick shaker activated.

2.5.2.2 Considering the occasionally challenging flying conditions along the Norwegian coast during the icing season, it would probably have been better had the commander not been assigned these routes until he had completed the annual UPRT training.

[38] The Oxford Learner's Dictionaries define resilience as follows: "the ability of people or things to recover quickly after something unpleasant, such as shock, injury, etc. "

[39] The Accident Investigation Board Norway (AIBN), SL 2016/11: *"Report on serious aviation incident at Svolvær Airport Helle on 2 December 2010 involving Bombardier DHC-8-103, LN-WIU, operated by Widerøe's Flyveselskap AS"*.

2.6 Other aspects

2.6.1.1 In its report SL 2011/15[40] the AIBN discussed various aspects related to safety and regulatory oversight in connection with wet lease and foreign operators. The report also discusses the operator's knowledge of local Norwegian conditions. The AIBN raised the issue again in a letter to the Ministry of Transport and Communications in connection with an aircraft incident at Kristiansand Airport Kjevik on 4 November 2016 with the airline Go2Sky, that operated scheduled flights for the airline Norwegian:

> *Leasing of aircraft to cover varying needs for capacity seems to be on the increase. This applies to both dry and wet lease agreements. This entails that safety oversight is split between several aviation authorities in different countries. In the AIBN's opinion, this entails an increased need for transfer of information, harmonisation of safety oversight practices and coordination between the authorities, if each aviation authority is to be able to satisfactorily monitor aircraft safety developments in its own country.*

The AIBN continued:

> *One might ask whether foreign operators and aviation authorities have sufficient knowledge for operations in a Norwegian climate and at Norwegian airports. The AIBN is of the opinion that this requires a great deal from the operators in ensuring that the companies they lease capacity from satisfy the standards they set for themselves. Important elements in such standards may exceed the minimum requirements set by the authorities.*

2.6.1.2 Consequently, the AIBN has reviewed the incident involving SAS4144 with a particular focus on any contributing factors that may be directly related to wet lease, foreign operators unfamiliar with Norwegian conditions, lack of transfer of information between the Scandinavian aviation authorities, and the possibility of the object of inspection (Jet Time AS) falling between two stools[41]. In this case, no such causal connections has been uncovered. Moreover, the AIBN has not uncovered any instances of authorities involved being in possession of information that could have contributed to preventing the incident had it been shared with the other aviation authorities.

2.6.1.3 In these assessments, the AIBN has focused on SAS4144 following a common route, and that there were no indications that a Norwegian operator would have chosen a different track. On the contrary, we have seen that the Widerøe flight, which was in the air more or less at the same time, chose an almost identical route.

2.7 Operations in Norway during the icing season

2.7.1.1 In the previous sections of this analysis, the AIBN discussed the interconnection between the loss of control and the crew's handling of OY-JZC. Important limitations and recommendations issued by the manufacturer were not complied with. The flight continued in severe icing conditions for at least 10 minutes, while the crew tried in vain

[40] The Accident Investigation Board Norway (AIBN), SL 2011/15: *"Report on serious aircraft incident at Bodø on 24 February 2008 involving a Sikorsky S-61N, G-ATFM operated by British International"*

[41] The AIBN discussed collaboration between supervisory authorities in its investigation report following an aircraft accident on 10 October 2006 at Stord Airport Sørstokken involving a BAE 146-200, OY-CRG, see report SL 2012/04

to escape the situation by climbing above the clouds. In the AIBN's opinion, this was the main contribution to the control loss.

2.7.1.2 However, the AIBN believes that focus also should be directed on the issue of aircraft type and specific performance in icing.

2.7.1.3 There is general agreement that the former certification regulations were not comprehensive enough, and that they did not sufficiently take into account recent knowledge about icing that emerged in the wake of the Roselawn accident, in particular the effect of supercooled large droplets (SLD). This means that the majority of existing aircraft types that are approved for operation in icing conditions could have significant differences in their ability to resist icing.

2.7.1.4 Compared with N401AM (ATR 72-212) that crashed in the Roselawn accident, OY-JZC (ATR 72-212A) was no doubt better equipped against icing. Although the aircraft operated in severe icing conditions for a relatively long period, the aircraft was not exposed to aileron hinge moment reversal, and it was possible to recover and continue the flight after control had been lost. The AIBN believes that a number of improvements of the aircraft model and better aircrew training have no doubt had a positive effect. It should also be taken into account that Jet Time AS had operated this aircraft model on Norwegian air routes for more than two years, apparently without any problems with icing.

2.7.1.5 While the AIBN appreciate the BEA comment concerning the comparison of the parallel climb profiles for SAS4144 and WIF564, the graphs still indicate the difference in aircraft performance, beginning at around FL100 which is the altitude where SAS4144 started to encounter icing. The graphs also serve to illustrate how degraded performance in icing may result in extended exposure to the adverse conditions if attempting to escape by continuing to climb.

2.7.1.6 Icing sensitivity does not appear to have been given special attention, neither by Jet Time AS, SAS, nor by the three Scandinavian authorities. Furthermore, it was not a topic covered by the Danish Transport, Construction and Housing Authority's inspections of Jet Time AS prior to the incident.

2.7.1.7 The AIBN also believes that it might have been unreasonable to expect that such sensitivity analyses should have been prepared before Jet Time AS started scheduled flights with the ATR 72 in Western Norway. After all, the aircraft model was certified for operation in icing conditions, and the version that was used had been subject to comprehensive modifications to make it more resistant to icing.

2.7.1.8 Based on this investigation, the AIBN would like to call attention to the following relating to operations during the icing season:

- The Norwegian icing season must be characterized as challenging, particularly along the coast.

- The icing certification of the majority of existing aircraft types do in fact give little or no guarantee of the aircraft's resistance and performance should it encounter freezing drizzle or rain (SLD).

- This and two other serious icing incidents involving the ATR 72-212A illustrates the importance of monitoring airspeed and climb in order to operate the aircraft within its defined performance limitations.

2.7.1.9 AIBN is of the opinion that icing should be a priority item in the risk analyses for airlines that plan to operate in Norway during the icing season, and that it is important to take the characteristics of the aircraft type into account. Such analysis should conjointly consider the flown routes, the flown flight levels, expected icing conditions, and mitigation actions to adverse conditions including icing, with regard to the aircraft type and specific performance.

3. CONCLUSIONS

3.1 Main conclusion

3.1.1 En route from Bergen to Ålesund control of SAS4144 was temporarily lost in severe icing conditions. The AIBN is of the opinion that the control loss was the result of insufficient planning and inappropriate decisions en route, such as the attempt to climb above the icing conditions despite degraded aircraft performance as well as use of the autopilot in altitude hold mode.

3.1.2 Recovery of control of the aircraft may have been impeded by the commander's initial response, pulling the control wheel back as the stick shaker activated. The commander is likely to have become startled when the aircraft stick shaker activated and the autopilot automatically deactivated, while the aircraft banked sharply, pitching its nose down. He may consequently have pulled on control wheel as the result of a temporary startle effect.

3.1.3 Another factor that contributed to the non-optimal recovery was that two memory items on the checklist for stalling, deploying flaps and increasing engine power, were omitted.

3.1.4 However, the crew quickly regained their composure and the rest of the flight and landing at Ålesund Airport Vigra proceeded without any further problems.

3.1.5 The AIBN is of the opinion that icing should be a priority item in risk analyses for airlines that plan to operate in Norway during the icing season, and that it is important to take the characteristics of the aircraft type into account. Such analysis should conjointly consider the flown routes, the flown flight levels, expected icing conditions, and mitigation actions to adverse conditions including icing, with regard to the aircraft type and specific performance.

3.2 Investigation results

3.2.1 General

a) The first officer had recently completed the annual UPRT training. The commander had not completed this training.

b) Despite certain indicator problems, the AIBN has not found anything to indicate that the aircraft's anti-icing systems were out of operation or did not function as intended, to such an extent that this could have affected the course of events.

c) A SIGMET for moderate icing was issued for the route.

d) Icing up to FL200 was forecast north of Bergen.

e) The crew did not know how high up the icing conditions prevailed along the entire route they were going to fly. According to their interpretation of the weather forecasts, icing would decrease above FL130 – 140.

3.2.2 The flight prior to loss of control

a) The crew activated all the aircraft's icing protection systems by the time the flight climbed through FL100.

b) OY-JZC was exposed to severe icing for at least 10 minutes before the stick shaker activated. This means that icing was so intense that the aircraft systems did not manage to prevent ice from accumulating.

c) When the aircraft encountered severe icing, the crew tried to climb above the clouds.

d) The airspeed during the final part of the climb was 165 kt, slightly below ICING BUG + 10 kt, which was 166 kt. This may have resulted in increased ice accretion on the aircraft.

e) After the crew gave up climbing above the icing conditions and levelled off at FL150, they engaged the autopilot altitude hold mode while the aircraft was still exposed to severe icing. Using the autopilot was not in accordance with the severe icing checklist.

f) After the crew decided to change course and head westward to escape the icing conditions, they communicated with Norway Control for 44 seconds, before changing course.

g) The autopilot initiated a left turn westward in high bank mode. The high bank angle was unfortunate and is likely to have contributed to the aircraft's loss of control.

h) The angle of attack increased during the turn, and the speed dropped suddenly, rapidly bringing the aircraft closer to stalling.

3.2.3 Loss of control

a) After the turn to the left was established, the stick shaker activated, the autopilot deactivated and the aircraft banked sharply to the left, pitching its nose down.

b) The first officer responded correctly, as she tried to push the control wheel forward when the stick shaker activated.

c) However, at the same time the commander responded by taking hold of the control wheel and incorrectly pulling it back.

d) The commander and first officer seem to have been unaware that they were applying opposite forces on the control wheel.

e) The stick pusher pushed the control column forward twice. Both times, the commander fought or tried to fight the pusher.

f) The crew appears not to have noticed that the stick pusher had activated.

g) The commander's initial response may have been the result of a so-called startle effect.

h) When the crew lost control of the aircraft, they failed to increase the engine power and extend the flaps, as dictated by the procedure for such situations.

i) After a 1,500 ft loss of altitude, the crew regained control of the aircraft.

j) At the lowest point, clearance to the ground was 7,600 ft or more.

3.2.4 The final part of the flight

a) The crew quickly regained their composure and the rest of the flight and landing in Ålesund proceeded without incident.

3.2.5 Other aspects

a) There were no findings indicating a connection between the course of events and the wet lease or the use of a foreign operator in Norway.

b) There were no findings indicating a connection between the course of events and any lack of transfer of information between the Scandinavian aviation authorities.

c) After the incident, ATR upgraded the computer logic preventing the autopilot to make a turn in high bank mode if the airspeed is below $VMHB0_{icing}$ + 20 kt, while the *degraded perf.* alert is displayed.

d) The icing certification of the majority of existing aircraft types do in fact give little or no guarantee of the aircraft's resistance and performance should it encounter freezing drizzle or rain (SLD).

e) It is therefore important also to take into account the characteristics of the aircraft type when airlines considers icing exposure in their flight operations risk analyses.

4. SAFETY RECOMMENDATIONS

The Norwegian Safety Investigations Authority issues no safety recommendations in connection with this investigation.

Norwegian Safety Investigations Authority

Lillestrøm, 9 September 2020

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APPENDICES

Appendix A: Abbreviations and acronyms

Appendix B: Weather report from the Norwegian Meteorological Institute

APPENDIX A: ABBREVIATIONS AND ACRONYMS

AAIB	Air Accidents Investigation Branch – the U.K. safety investigation authority
AAS	Anti-icing Advisory System
AIBN	Accident Investigation Board Norway
ADF	Air Data Computer
AFM	Airplane Flight Manual
AIRMET	Airmen's Meteorological Information
AOA	Angle of Attack
AOC	Air Operator Certificate
APM	Aircraft Performance Monitoring
ATPL(A)	Air transport pilot license - aeroplanes
ATR	GIE Avions de Transport Régional
AUPRTA	Aeroplane Upset Prevention and Recovery Training Aid
BEA	Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile – the French safety investigation authority
CAE	Canadian aviation training organization
CBT	Computer based training
CIAIAC	Comisión de Investigación de Accidentes e Incidentes de Aviación Civil – the Spanish safety investigation authority
CPL(A)	Commercial pilot license - aeroplanes
CRM	Crew Resource Management
CRZ	Cruise
CS	Certification Specifications (common European standard for type certification)
CVR	Cockpit Voice Recorder
CL	Condition Lever
daN	dekaNewton, 1 daN = 10 N ≈ 1 kilo force
DAR-file	Disk Archiver Compressed Archive file

EASA	European Aviation Safety Agency
EDORA	Electronic Documentation for Regional Aircraft
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Training Manual
FDAU	Flight Data Acquisition Unit
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FL	Flight Level (FL100 is approximately 10 000 ft)
FMA	Flight Mode Annunciator
ft/min	feet per minute
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IOSA	IATA Operational Safety Audit
IR	Instrument Rating
JAR	Joint Aviation Regulations (former common European standard for type certification)
kt	knot – nautical miles per hour
LOFT	Line Oriented Flight Training
MCT	Maximum Continuous Thrust
MEF	Maximum Elevation Figure
MSIS	Minimum Severe Icing Speed
MTOW	Maximum Take-Off Weight
NTSB	National Transportation Safety Board – the American safety investigation authority (USA)
OM-A	Operations Manual – Part A
OM-B	Operations Manual – Part B
OPC	Operations Proficiency Check
PCMCIA	Personal Computer Memory Card International Association – memory card standard

PF	Pilot Flying
PFD	Primary Flight Display
PL	Power Lever
PM	Pilot Monitoring
PWR MGT	Power Management
QAR	Quick Access Recorder
QRH	Quick Reference Handbook
RA	Resolution Advisory
SAS	Scandinavian Airlines System Denmark-Norway-Sweden
SEV ICE	Severe Icing
SIGMET	Significant Meteorological Information
SHP	Shaft horsepower
SMS	Safety Management System
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
TAT	Total Air Temperature
TCAS	Traffic Alert and Collision Avoidance System
UPRT	Upset Prevention and Recovery Training
UTC	Coordinated Universal Time

APPENDIX B: WEATHER REPORT FROM THE NORWEGIAN METEOROLOGICAL INSTITUTE

TAF ENBR:
2016-11-14 05:00:00 ENBR 140500Z 1406/1506 16020G30KT 9999 -RA SCT008 BKN012 TEMPO 1406/1411 4000 RA BKN008 TEMPO 1411/1418 2000 RADZ BR BKN004 BECMG 1411/1414 VRB07KT BECMG 1422/1502 16018G30KT TEMPO 1500/1506 2000 RADZ BR BKN004 BECMG 1504/1506 24015KT=
AMD TAF
2016-11-14 05:00:00 ENBR 140815Z 1408/1506 16020G30KT 9999 -RA SCT008 BKN012 TEMPO 1408/1418 1200 RADZ BR BKN003 BECMG 1411/1414 VRB07KT BECMG 1422/1502 16018G30KT TEMPO 1500/1506 2000 RADZ BR BKN004 BECMG 1504/1506 24015KT=

METAR ENBR:
ENBR 140520Z 15016KT 9999 RA FEW009 BKN017 07/06 Q1017 TEMPO 4000 RA BKN008 RMK WIND 1200FT 15033G47KT=
ENBR 140550Z 15019KT 9000 RA FEW008 SCT012 BKN017 07/06 Q1016 TEMPO 4000 RA BKN008 RMK WIND 1200FT 15035KT=
ENBR 140620Z 15017G28KT 9000 RA FEW008 SCT014 BKN017 07/06 Q1015 TEMPO 4000 RA BKN008 RMK WIND 1200FT 15033G44KT=
ENBR 140650Z 15019KT 9000 RA FEW008 BKN015 07/06 Q1015 TEMPO 4000 RA BKN008 RMK WIND 1200FT 15034G47KT=
ENBR 140720Z 15017KT 9000 -RA FEW008 BKN016 07/06 Q1015 TEMPO 4000 RA BKN008 RMK WIND 1200FT 15032G45KT=
ENBR 140750Z 15019KT 4000 RADZ BR FEW006 BKN008 07/06 Q1014 TEMPO 2000 RADZ BR BKN004 RMK WIND 1200FT 15033G47KT=
ENBR 140820Z 15018G28KT 3500 RADZ BR FEW005 BKN010 07/06 Q1014 TEMPO 2000 RADZ BR BKN004 RMK WIND 1200FT 15034KT=
ENBR 140850Z 15020KT 9000 -RA FEW003 SCT006 BKN010 08/07 Q1014 TEMPO 2000 RADZ BR BKN004 RMK WIND 1200FT 15034G44KT=
ENBR 140850Z 15020KT 9000 -RA FEW003 SCT006 BKN010 08/07 Q1014 RMK WIND 1200FT 15034G44KT=

TAF ENAL:
2016-11-14 05:00:00 ENAL 140500Z 1406/1415 19012KT 9999 -RA FEW020 BKN040 TEMPO 1406/1410 20020G30KT RA BECMG 1410/1412 22020G30KT TEMPO 1410/1414 4000 RA BKN010 BECMG 1413/1415 25015KT=
2016-11-14 08:00:00 ENAL 140800Z 1409/1418 19012KT 9999 -RA FEW020 BKN035 TEMPO 1409/1410 20020G30KT RA BECMG 1410/1412 22020G30KT TEMPO 1410/1414 4000 RA BKN010 BECMG 1413/1415 25015KT=

METAR ENAL:
ENAL 140520Z 19015KT 9999 -RA BKN042 10/05 Q1008=
ENAL 140550Z 20013KT 9999 -RA BKN042 10/05 Q1008 REDZ=
ENAL 140620Z 19013KT 9999 -RA BKN042 10/05 Q1007 REDZ=
ENAL 140650Z 19013KT 9999 SHRA BKN042 10/06 Q1007=
ENAL 140720Z 20012KT 9999 -RA BKN042 10/06 Q1007=
ENAL 140750Z 20012KT 170V230 9999 -DZ FEW021 BKN047 10/06 Q1007=
ENAL 140820Z 20014KT 9999 DZ FEW023 BKN044 10/06 Q1007=
ENAL 140850Z 20011KT 9999 DZ BKN040 10/06 Q1007=

AIRMET-ER:
WAN032 ENMI 140236
ENSV AIRMET B01 VALID 140300/140700 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N5700 E00730 - N5700 E00500 - N6000 E00000 - N6300 E00000 -

N6300 E00400 - N6200 E00500 - N6200 E00730 - N5700 E00730 FL035/200 MOV E NC

WANO32 ENMI 140649
ENSV AIRMET B02 VALID 140700/141100 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N5700 E00730 - N5700 E00500 - N5945 E00030 - N6300 E00045 - N6300 E00400 - N6200 E00500 - N6200 E00730 - N5700 E00730 FL035/200 MOV E NC

WANO34 ENMI 140355
ENBD AIRMET C02 VALID 140400/140800 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N6200 E01000 - N6200 E00500 - N6300 E00400 - N6500 E00605 - N6500 E01300 - N6200 E01000 FL060/200 MOV ENE NC

SIGMET-ER

WSNO32 ENMI 140641

ENSV SIGMET B02 VALID 140645/141045 ENVV-
ENOR NORWAY FIR OCNL SEV TURB FCST WI N6100 E00730 - N6100 E00500 - N6200 E00500 - N6200 E00730 - N6100 E00730 SFC/FL100 STNR WKN

WSNO34 ENMI 140641

ENBD SIGMET C02 VALID 140645/141045 ENVV-
ENOR NORWAY FIR OCNL SEV TURB FCST WI N6200 E00730 - N6200 E00500 - N6300 E00730 - N6200 E00730 SFC/FL100 STNR WKN

WSNO32 ENMI 140740

ENSV SIGMET B03 VALID 140740/141100 ENVV-
ENOR NORWAY FIR OCNL SEV ICE OBS WI N5840 E00730 - N5900 E00520 - N6200 E00500 - N6200 E00730 - N5840 E00730 FL035/160 STNR NC

UANO62 ENMI 140723

AIREP SPECIAL
ARS AT76 SEV ICE OBS AT 0710Z OHD ENBL FL150

IGA sør for Stad:

FBNO42 ENMI 140511

IGA PROG 140500-141500 UTC Nov 2016 NORWAY FIR SW PART COAST AND FJORD AREAS W OF E00730 AND S OF N6200

WIND SFC.......: SE-S/15-25KT, 25-35KT COT, 35-40KT COT N-PART, 45-50KT NEAR STAD, DECR LATE FORENOON, BECMG S-SW/05-15KT LATE VRB/05-10KT OR W-LY/10KT
WIND 2000FT....: S-SW/25-40KT, 40-50KT N-PART, 55-65KT NEAR STAD, DECR LATE FORENOON, BECMG SW-W/15-25KT LATER W-LY/10-15KT
WIND/TEMP FL050: 230-240/25-40KT, 40-50KT N-PART, 55-60KT OHD STAD DECR, BECMG 250-270/15-25KT / MS02-PS03 LOWEST S-PART, BECMG PS04-PS06 S-PART
WIND/TEMP FL100: 240-260/25-35KT, 40-50KT N-PART BECMG 270-290/30-40KT / MS04-MS01

```
WX............: SCT RA, LATER RADZ/BR
VIS...........: +10KM, LCA 3-7KM IN RA, LATER LCA 2-5KM IN RADZ/BR
CLD...........: SCT/BKN 1000-2000FT, LCA BKN 0600-1000FT, LATER LCA BKN 0300-0600FT IN WX
0-ISOTHERM....: 3000FT-FL070, LOWEST S-PART FST HR, LCA INVERSION
ICE...........: MOD, OCNL MOD/SEV, BECMG FBL/MOD, OCNL MOD, LATE FBL
TURB..........: MOD, OCNL SEV N-PART DECR, BECMG FBL, OCNL FBL/MOD
```

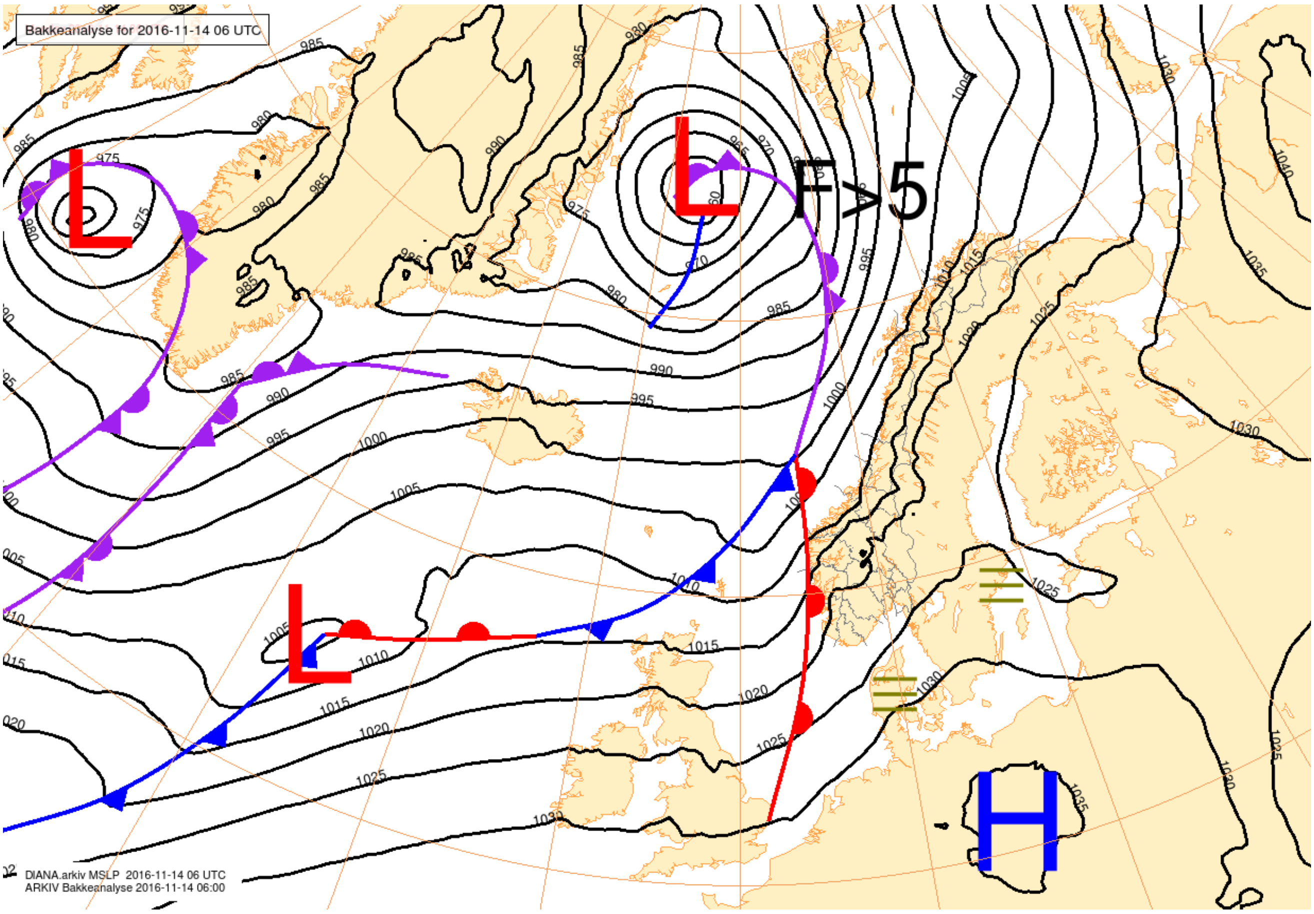
IGA nord for Stad:

```
FBNO44 ENMI 140511

 IGA PROG 140500-141500 UTC Nov 2016 NORWAY FIR COASTAL AND FJORD AREAS N6200 TO N6500


WIND SFC.......: SE-S/10-20KT, LCA 25-35KT. S-PART: BECMG LATE MORNING SW/25-40KT COT, LATE DECR
10-15KT. N-PART: LATE BECMG S-SW/15-25KT COT
WIND 2000FT....: S-SW/30-40KT, 45-65KT SW-PART, AFTERNOON DECR S-SW/15-25KT LCA 30KT N-PART
WIND/TEMP FL050: 220-240/35-45KT, 50-60KT SW-PART. AFTERNOON DECR 240-270/20-30KT / 00-PS04
WIND/TEMP FL100: 220-250/35-45KT, AFTERNOON DECR 250-270/25-30KT / MS05-MS01
WX.............: RA/DZ/BR
VIS............: +10KM, LCA 3-7KM IN WX
CLD............: BKN/OVC 2000-4000FT, 5000-8000FT N-PART EARLY. BECMG LCA BKN 0700-1200FT
0-ISOTHERM.....: FL050-080
ICE............: MOD, AFTERNOON BECMG FBL/NIL SW-PART
TURB...........: SW-PART: OCNL SEV, DECR FBL LATE MORNING. N-PART: MOD, AFTERNOON BECMG FBL
```

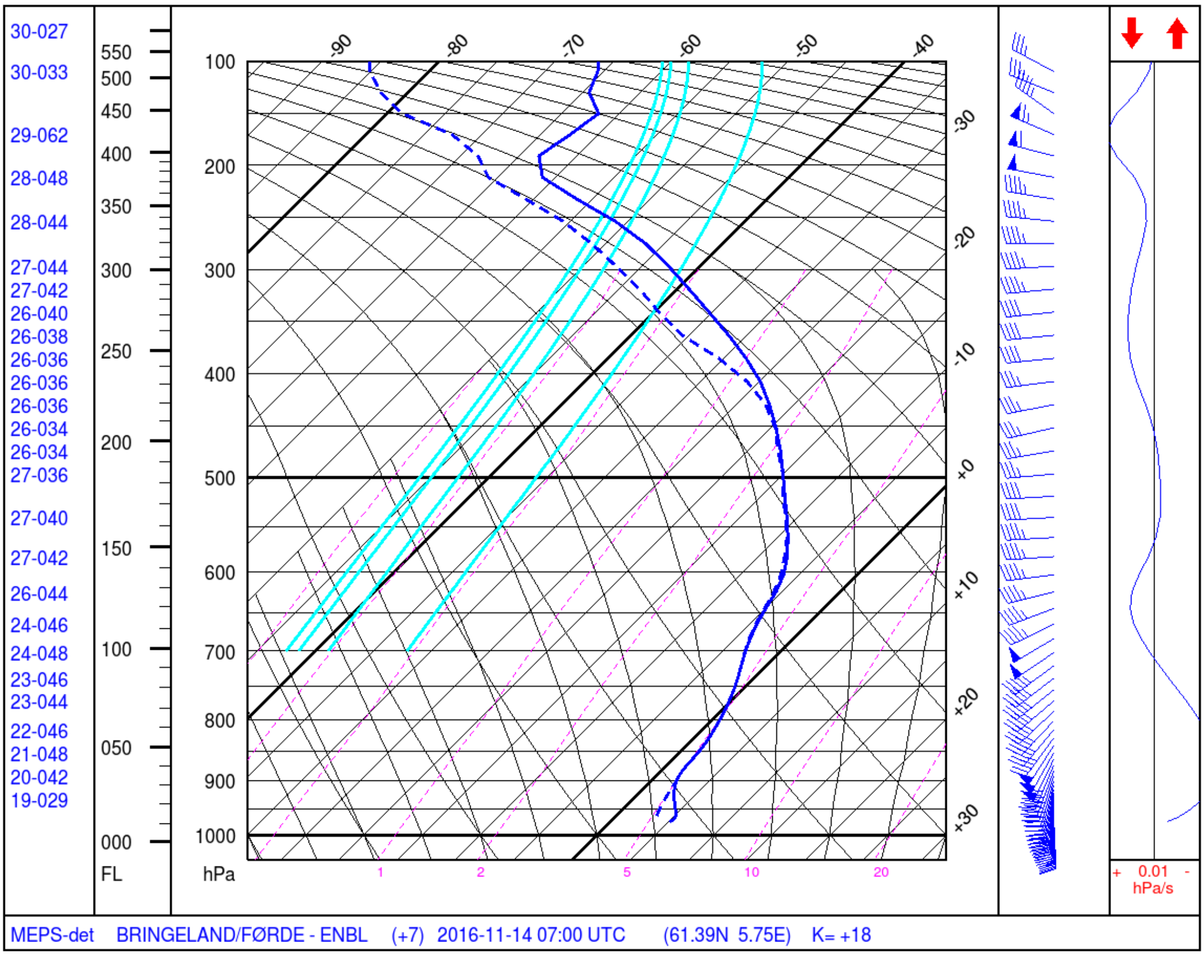
Vær- og isingsforhold strekingen ENBR-ENBL mandag 14. november 2016 omkring kl 0700 UTC:

Et lavtrykk nord i Norskehavet ga sørlig vind på Vestlandet sør for Stad, helt opp i liten storm 22 m/s ved Stad, litt mindre lenger sør. En varmfront lå nær kysten.

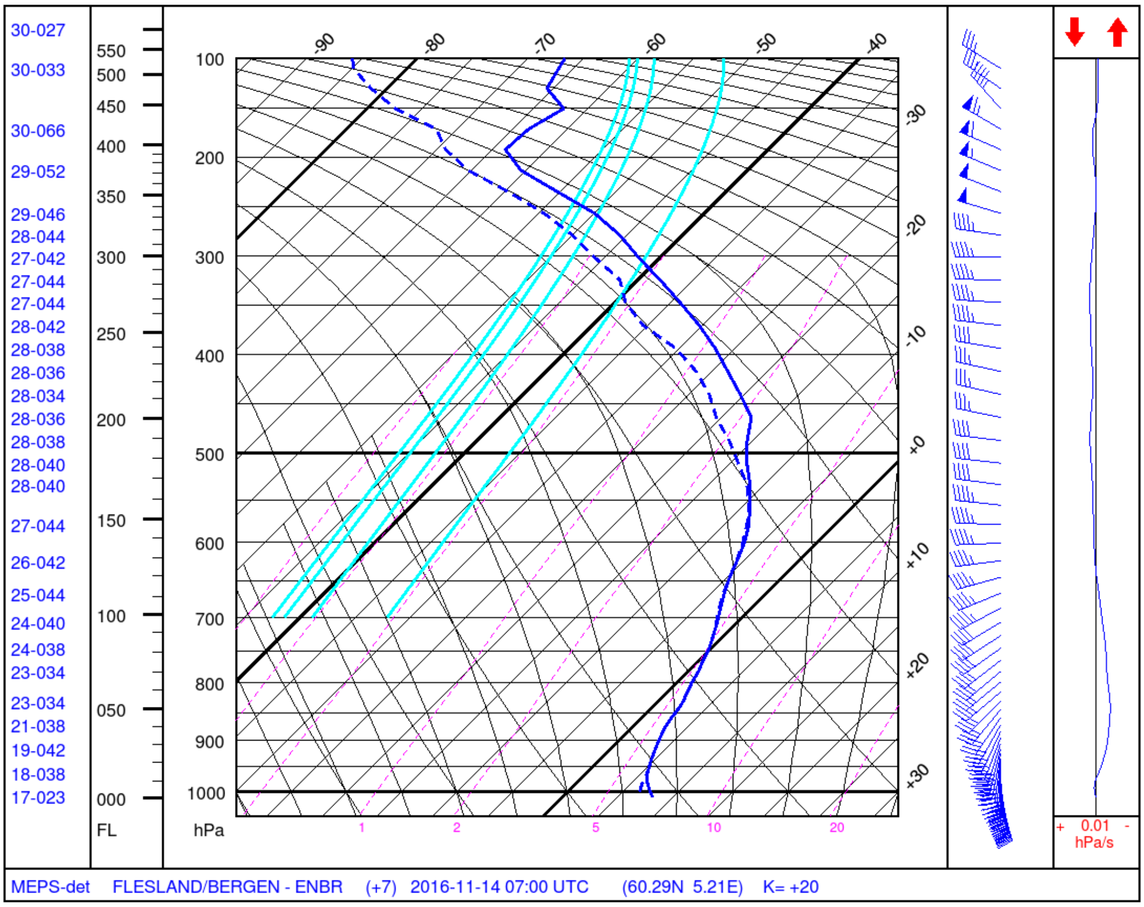
Dette er forhold som nok ga en del ising. Bakkevinden kom fra sør, litt lenger oppe var det sørvest til vest og dermed orografisk heving av luftmassene. Det var mest sannsynlig moderat ising de fleste steder, noe mer der hvor hevingen av luftmasser var størst. SIGMET på SEV ICE ble diskutert, men det ble vurdert til å være moderat ising, om enn nær sterk. Etter at rapporten om SEV ICE kom, ble det, i henhold til prosedyre, gjort nye vurderinger, og det ble sendt SIGMET på SEV ICE. Det ble ikke innrapportert andre tilfeller av moderat eller kraftig ising.



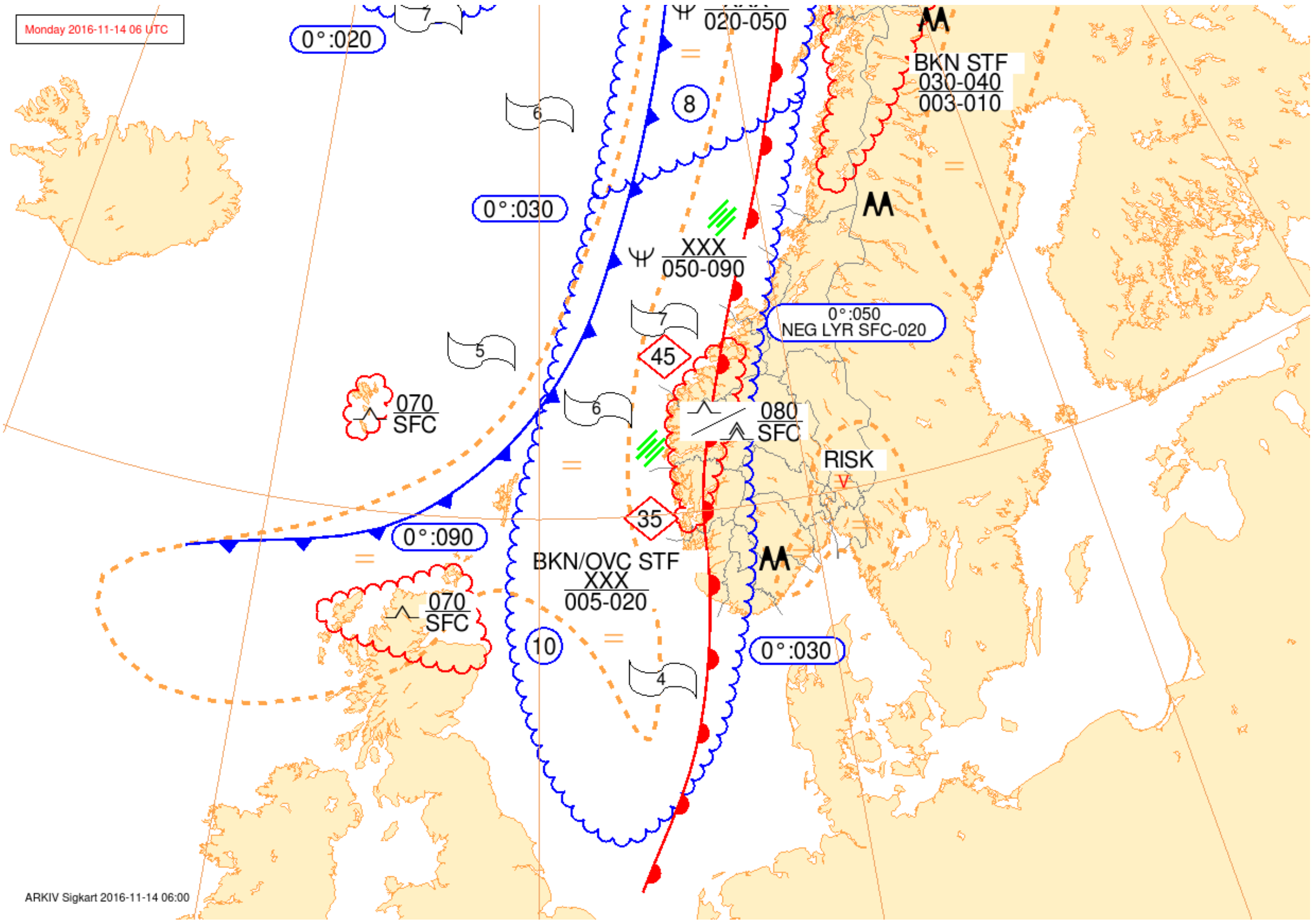
Analyse kl 0600 UTC 14. november. Varmfront langs kysten av Vestlandet.



Figuren over viser temperaturprofil over ENBL kl 0700 utc. Temperatur er hel linje, duggpunktstemperatur er stiplet. Sørvest vind i høyden og fuktig luft (temperatur og duggpunkt er like) viser at der er venta ising mellom ca FL080 til FL200.



Figuren over viser temperaturprofil over ENBR kl 0700 utc. Ganske lik profilet fra ENBL, men det er litt svakere vind og isingen går ikke like høyt.



SIGWX-kart gjeldene 0600 utc 14. november. Det viser at det var vente moderat ising og lokalt kraftig turbulens på strekningen ENBR-ENBL.