AirSafe.com - Additional Resources and Offers

Thanks for downloanding this document from AirSafe.com. We'd like to make you aware of some of our special offers and resources:

Other Online Resources

Airline Safety: AirSafe.com, AirSafeNews.com , Plane-Crash-Videos.net, FlightsGoneBad.com

Airline Baggae: AirSafe.com Baggage and Security Guide

Fear of Flying: fear.airsafe.org **-** Featuring services offered by the SOAR fear of flying organization

Investing Advice: MoneyBahn.com - for free educational seminars offers, join the mailing list

Online marketing: AirSafe-Media.com

Special Offers: If you want to receive special offers from Dr. Curtis, including free advice on dealing with airline safety, and other free offers, please subscribe to the AirSafeNews.com mailing list.

Dr. Todd Curtis has also created a number of other online resources:

Airline Safety: AirSafe.com, and AirSafeNews.com

Investing Advice: MoneyBahn.com

Online marketing: AirSafe-Media.com

Keep in touch with Dr. Curtis and AirSafe.com:

Facebook: facebook.com/airsafe

LinkedIn: www.linkedin.com/in/airsafe

Twitter: twitter.com/airsafe

Email: tcurtis@airsafe.com

f-cp090601ae

Interim report

on the accident on **1st June 2009**
to the **Airbus A330-203**
registered **F-GZCP**
operated by **Air France**
flight AF 447 Rio de Janeiro – Paris

BEA

Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

Ministère de l'écologie, de l'énergie, du développement durable et de la mer, en charge des technologies vertes et des négociations sur le climat

Foreword

This document has been prepared on the basis of the initial information gathered during the investigation, without any analysis and - given the continuing absence of wreckage, the flight recorders, radar tracks and direct testimony - without any description of the circumstances of the accident. Some of the points covered may evolve with time. Nothing in the presentation of this interim report or in the points that are raised therein should be interpreted as an indication of the orientation or conclusions of the investigation.

In accordance with Annex 13 to the Convention on International Civil Aviation, with EC directive 94/56 and with the French Civil Aviation Code, the investigation is not conducted in such a way as to apportion blame or to assess individual or collective responsibility. The sole objective is to draw lessons from this occurrence which may help to prevent future accidents or incidents

SPECIAL FOREWORD TO ENGLISH EDITION

This interim report has been translated and published by the BEA to make its reading easier for English-speaking people. As accurate as the translation may be, the original text in French should be considered as the work of reference.

Table of Contents

Glossary

AAIB	Air Accident Investigation Branch
ACARS	Aircraft Communications Addressing and Reporting System
ACP	Audio Control Panel
ADIRU	Air Data and Inertial Reference Unit
ADM	Air Data Module
ADR	Air Data Reference
ADS-C	Automatic Dependent Surveillance-Contract
AFS	Automatic Flight System
AIC	Aeronautical Information Circular
AMU	Audio Management Panel
AOC	Airline Operational Control
ASECNA	Air Traffic Safety Agency for Africa and Madagascar
ATA	Air Transport Association of America
ATC	Air Traffic Control
ATPL	Airline Transport Pilot License
ATSU	Air Traffic Service Unit
BFU	German accident investigation board (Bundesstelle für Flugunfallunteruchung)
BITE	Built-In Test Equipment
SB	Service Bulletin
CAS	Calibrated Airspeed
CAT	Clear Air Turbulence
OCC	Operations Coordination Centre
ECC	En-route Control Centre
RCC	Rescue Coordination Centre
CDL	Configuration Deviation List
CECLANT	Atlantic Command
CENIPA	Brazilian accident investigation board (CENtro de Investigação e Prevenção de Acidentes aeronãuticos)
CFR	Current Flight Report
CG	Centre of Gravity
CMC	Central Maintenance Computer
CMS	Central Maintenance System
CNOA	French national operations centre
CPDLC	Controller-Pilot DataLink Communications
CPL	Commercial Pilot's Licence
DGAC	French civil aviation directorate (Direction Générale de l'Aviation Civile)
DMC	Display Management Computer

ECAM	Electronic Centralized Aircraft Monitoring
EFCS	Electronic Flight Control System
ETOPS	Extended-range Twin-engine OPerationS
EWD	Engine Warning Display
FADEC	Full Authority Digital Engine Control
FCDC	Flight Control Data Concentrator
FCL	Flight Crew Licensing
FCMS	Fuel Control Monitoring System
FCOM	Flight Crew Operating Manual
FCPC	Flight Control Primary Computer
FCSC	Flight Control Secondary Computer
FCTM	Flight Crew Training Manual
FD	Flight Director
FIR	Flight Information Region
FL	Flight Level
FM	Flight Management
FMGEC	Flight Management Guidance and Envelope Computer
FMS	Flight Management System
FPV	Flight Path Vector
FWS	Flight Warning System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HF	High Frequency
IATA	International Air Transport Association
IFPS	Initial Flight plan Processing System
IR	Inertial Reference
IRME	Multi Engine Instrument Rating
ISIS	Integrated Standby Instrument System
kHz	kilo Hertz
kt	knot
LMC	Last Minute Change
MAC	Mean Aerodynamic Chord
MEL	Minimum Equipment List
METAR	METeorological Airport Report
MHz	Mega Hertz
MRCC	Maritime Rescue Coordination Centre
MTOW	Maximum Takeoff Weight
ND	Navigation Display
NM	Nautical Mile
NOTAM	NOTice to AirMen

NTSB	National Transportation Safety Board (USA)
ICAO	International Civil Aviation Organisation
PF	Pilot Flying
PFD	Primary Flight Display
PFR	Post Flight Report
RCC	Rescue Coordination Centre
RMP	Radio Management Panel
ROV	Remotely Operated Vehicle
SAR	Search and Rescue
SD	System Display
SELCAL	SELective CALling system
SIGMET	SIGnificant METeorological information
TAF	Terminal Area Forecast
TCAS	Traffic alert and Collision Avoidance System
TEMSI	Significant weather chart
TPL	Towed Pinger Locator
ULB	Underwater Locator Beacon
USCG	US Coast Guard
UTC	Universal Time Coordinated
VHF	Very High Frequency
ITCZ	Inter-Tropical Convergence Zone

Synopsis

Date of accident
1st June 2009 at around 2 h 15(1)

Site of accident
Near the TASIL point
in international waters
Atlantic Ocean

Type of flight
International public transport
of passengers
Scheduled flight AF447

Aircraft
Airbus A330-203
registered F-GZCP

Owner
Air France

Operator
Air France

Persons on board
Flight crew: 3
Cabin crew: 9
Passengers: 216

(1)All times in this report are UTC, except where otherwise specified. Two hours should be added to obtain the legal time applicable in metropolitan France on the day of the incident. The estimated time of the accident is based on the interruption in the ACARS messages.

Summary

On 31 May 2009, flight AF447 took off from Rio de Janeiro Galeão airport bound for Paris Charles de Gaulle. The airplane was in contact with the Brazilian ATLANTICO ATC centre on the INTOL – SALPU – ORARO route at FL350. There were no further communications with the crew after passing the INTOL point. At 2 h 10, a position message and some maintenance messages were transmitted by the ACARS automatic system. Bodies and airplane parts were found from 6 June 2009 onwards by the French and Brazilian navies.

Consequences

	People			Equipment
	Killed	Injured	Unhurt	
Crew	12	-	-	Destroyed
Passengers	216	-	-	
Third parties	-	-	-	

ORGANISATION OF THE INVESTIGATION

On Monday 1st June 2009 at around 7 h 45, the BEA was alerted by the Air France Operations Coordination Centre, which had received no news from flight AF447 between Rio de Janeiro Galeão (Brazil) and Paris Charles de Gaulle. After having established without doubt that the airplane had disappeared in international waters and in accordance with Annex 13 to the Convention on International Civil Aviation and to the French Civil Aviation Code (Book VII), the BEA launched a technical investigation and a team was formed to conduct it.

In accordance with the provisions of Annex 13, Brazilian, American, British and German accredited representatives were associated with the investigation as the State of the engine manufacturer (NTSB) and because they were able to supply essential information to the investigation (CENIPA, AAIB and BFU). The following countries also nominated observers as some of their citizens were among the dead:

- China,
- Croatia,
- Hungary,
- Ireland,
- Italy,
- Korea,
- Lebanon,
- Morocco,
- Norway,
- Russia,
- South Africa,
- Switzerland.

The Investigator-in-Charge initially set up four working groups to determine and gather the information required for the investigation in the following areas:

- Sea searches,
- Maintenance,
- Operations,
- Systems and equipment.

Investigation teams were also sent to Brazil, Senegal and to sea, in the area where the airplane disappeared.

All of the operations that have been undertaken on the site or on the airplane parts have been coordinated with those responsible for the judicial investigation.

1. FACTUAL INFORMATION

1.1 History of Flight

On Sunday 31 May 2009, the Airbus A330-203 registered F-GZCP operated by Air France was programmed to perform scheduled flight AF447 between Rio de Janeiro Galeão and Paris Charles de Gaulle. Twelve crew members (3 flight crew, 9 cabin crew) and 216 passengers were on board. The departure was planned for 22 h 00.

Towards 22 h 10, the crew was cleared to start up engines and leave its parking position. Takeoff took place at 22 h 29.

The takeoff weight was 232.8 t (for a MTOW of 233 t), including 70.4 t of fuel.

The crew contacted, successively:

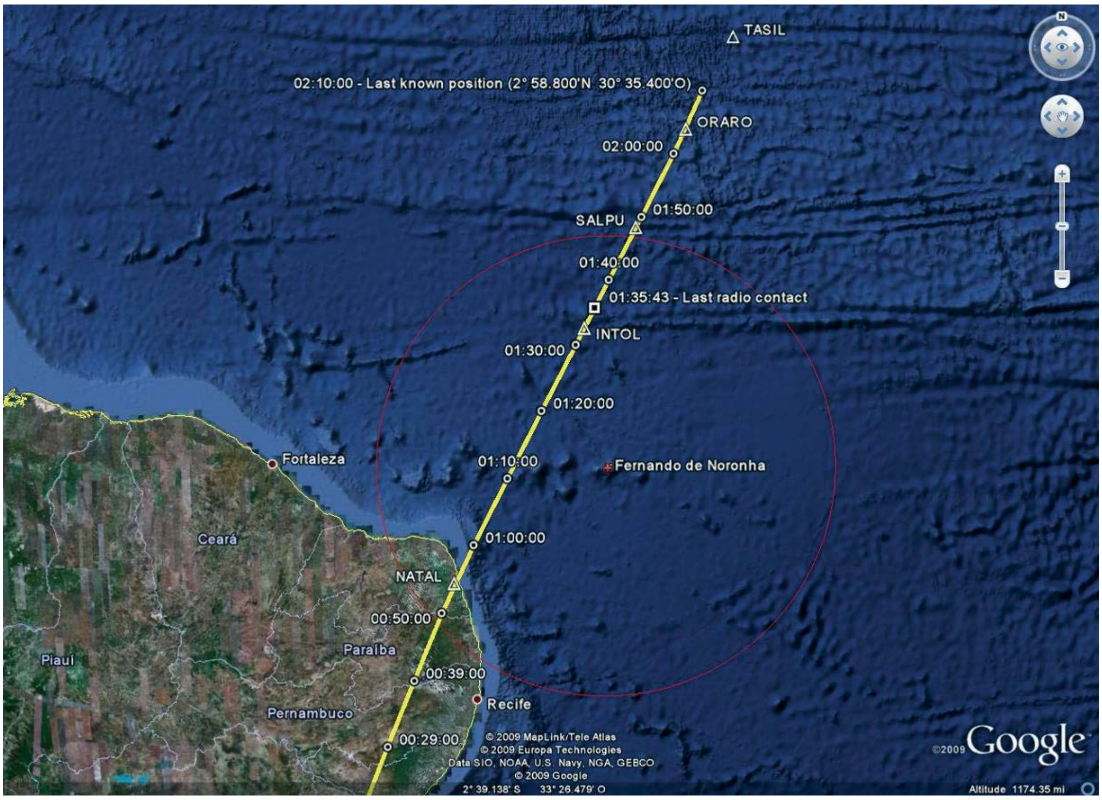
- RIO DE JANEIRO approach control,
- the CURITIBA ATC centre, which cleared it to climb to FL350 at 22 h 45 min 26,
- the BRASILIA ATC centre at 22 h 55 min 41,
- the RECIFE ATC centre at 23 h 19 min 27, the airplane being stable at FL350,
- the ATLANTICO ATC centre on HF at 1 h 33 min 25.

At 1 h 35 min 15, the crew informed the ATLANTICO controller that they had passed the INTOL[(2)] point then announced the following estimated times: SALPU at 1 h 48 then ORARO at 2 h 00. They also transmitted their SELCAL code and a test was performed.

[(2)]INTOL, SALPU, ORARO and TASIL are civil aviation reporting points.

At 1 h 35 min 46, the controller asked them to maintain FL350 and to give their estimated time at the TASIL point.

Between 1 h 35 min 53 and 1 h 36 min 14, the controller asked the crew three times for its estimated time at the TASIL point. There was no further contact with the crew.



1.2 Killed and Injured

Injuries	Crew Members	Passengers	Others
Fatal	12	216[3]	0
Serious	0	0	0
Light/none	0	0	0

[3]Including one baby.

1.3 Damage to Aircraft

Between 6 and 20 June 2009, numerous airplane parts were recovered from the sea.

1.4 Other Damage

Not applicable.

1.5 Personnel Information

Given the length of the planned flight and in compliance with the Air France operations manual and with the regulations in force, the flight crew was reinforced.

The regulation defines reinforced crew as follows:

Flight crew where the number of members is greater than the minimum number required for the operation of the airplane and within which each member of the flight crew is able to leave his or her station and be replaced by another member of the flight crew with the appropriate qualification[4].

The airline's procedures[5] specify that to be a replacement duty pilot, a crew member must have the same rating as the crew member that he or she is replacing and, in addition, during the captain's rest period, a pilot with the same license as the captain must be at the controls.

[4]Regulation N° 859/2008 of the European Commission of 20 August 2008, paragraph 1.1095.

[5]GEN.OPS 1.7.02.00

From the current state of the information gathered, it is not possible to determine the composition of the flight crew on duty at the time of the event.

Note: the crew left Paris on Thursday 28 May 2009 in the morning and arrived in Rio de Janeiro in the evening of the same day.

1.5.1 Flight crew

1.5.1.1 Captain

Male, aged 58

- Air Transport Pilot's License (ATPL) issued 8 March 1990, MTOW limitation of 20,000 kg
- ATPL License without limitations issued 19 February 1992
- Captain since 19 June 1998
- Professional pilot instructor 1st class (IPP1) rating issued 31 March 1993

- Airbus A330 type rating obtained on 27 October 2006
- Line oriented flight training completed on 17 February 2007

- Airbus A340 type rating obtained on 9 August 2007

- Line oriented flight training on 7 September 2007

- Medical certificate (class 1) issued on 10 October 2008, valid until 31 October 2009

- Other type ratings: Caravelle XII, Airbus A320 and Boeing 737

- Flying hours:
  - total: 10,988 flying hours, of which 6,258 as Captain
  - hours on type: 1,747[6], all as Captain
  - in the previous six months: 346 hours, 18 landings, 15 take-offs
  - in the previous three months: 168 hours, 8 landings, 6 take-offs
  - in the previous 30 days: 57 hours, 3 landings, 2 take-offs

[6]Of which 1,093 flying hours on Airbus A330 and 654 on Airbus A340.

The captain had carried out sixteen rotations in the South America sector since he arrived in the A330/A340 division in 2007. His oceanic route qualification was valid until 31 May 2010.

2008/2009 and 2009/2010 ECP instruction seasons:

- A340 (E34) training on 11 October 2008
- A330 (C33) base check on 12 October 2008
- A330 (E33) training on 22 April 2009
- A340 (C34) base check on 23 April 2009
- A340 (CEL34) line check on 21 July 2008
- A340 (CEL34) line check on 7 September 2007
- A330 (CEL33) line check on 15 February 2007
- S1 ground training on 12 January 2009
- 4S ground training on 7 August 2008

Note: the instruction season goes from 1st April to 31 March the following year.

1.5.1.2 Co-pilot

Male, aged 37

- ATPL license issued 13 April 2001

- Airbus A340 type rating issued 14 February 2002
- Line oriented flight training completed 13 April 2002

- Airbus A330 type rating issued 1st October 2002
- Line oriented flight training completed 25 October 2002

- Other type ratings: Airbus A320 issued in February 1999

- Medical certificate (class 1) issued 11 December 2008, valid until 31 December 2009 with compulsory wearing of corrective lenses.

- Flying hours:
  - total: 6,547 flying hours
  - on type: 4,479 flying hours[7]
  - in the previous six months: 204 hours, 9 landings, 11 take-offs
  - in the previous three months: 99 hours, 6 landings, 5 take-offs
  - in the previous thirty days: 39 hours, 2 landings, 2 take-offs

[7] Of which 2,597 flying hours on Airbus A340 and 1,882 hours on Airbus A330.

This pilot's licences allowed him to perform the duties of replacement pilot in place of the captain.

He also acted as flight crew representative officer at the operator's OCC.

May activity at the OCC:

- 12 May from 6 h to 16 h,
- 13 May 16 h to 14 May 6 h,
- 17 May from 6 h to 16 h,
- 18 May 16 h to 19 May 6 h,
- from 20 May 8 h to 22 May 17 h[8]

[8] During this period, the copilot was not present at the OCC but was on telephone stand-by duty.

This pilot had performed 39 rotations on the South America sector since arriving in the A330/A340 division in 2002. His oceanic route qualification was valid until 28 February 2010.

2008/2009 and 2009/2010 ECP instruction seasons:

- E34 training on 22 July 2008
- C33 base check on 23 July 2008
- E33 training on 6 December 2008
- C34 base check on 21 December 2008
- CEL34 line check on 30 October 2007
- CEL33 line check on 26 October 2008
- S1 ground training on 18 March 2009
- 4S ground training on 10 December 2008

1.5.1.3 Co-pilot

Male, aged 32

- Professional pilot's FCL license (CPL) issued on 23 April 2001
- Multi-engine instrument type rating (IR ME) issued on 16 October 2001
- ATPL theory obtained in September 2000

- Airbus A340 type rating issued on 26 February 2008
- Line oriented flight training completed 9 June 2008

- Airbus A330 type rating issued on 1st December 2008
- Line oriented flight training completed 22 December 2008

- Other type ratings: Airbus A320 issued on 7 September 2004

- Medical certificate (class 1) issued on 24 October 2008, valid until 31 October 2009 with compulsory wearing of corrective lenses

- Flying hours:
  - total: 2,936
  - on type: 807[9]
  - in the previous six months: 368 hours, 16 landings, 18 take-offs
  - in the previous three months: 191 hours, 7 landings, 8 take-offs
  - in the previous thirty days: 61 hours, 1 landing, 2 take-offs

This pilot had performed five rotations in the South America sector since arriving in the A330/A340 division in 2008, including one to Rio de Janeiro. His oceanic route qualification was valid until 31 May 2010.

2008/2009 ECP instruction season:

- E33 training on 2 February 2009
- C34 base check on 3 February 2009
- 4S ground training on 15 January 2009

The validity of the E34, C33, CEL34, CEL33, S1 training, checks and ground training was covered by the dates he obtained the Airbus A330 and A340 type rating qualifications as well as by the date of the end of the line oriented flight training.

These training courses and checks were programmed before the following dates:

- E34 training: 31 August 2009
- C33 base check: 31 August 2009
- CEL34 line check: 31 December 2009
- CEL 33 line check: 31 December 2010
- S1 ground training: 31 March 2010

1.5.2 Cabin crew

For this airplane, the regulatory minimum cabin crew composition as provided for in the Operations Manual[10] is five people.

On flight AF447, nine members of the crew were on duty in the passenger cabin:

- one senior flight attendant, qualified on the A330/A340 type airplane,
- two pursers, qualified on the A330/A340,
- three cabin crew members, qualified on the A330/A340 (cabin crew required by regulations),
- two additional cabin crew members, not fully qualified on the A330/A340 (additional cabin crew to the minimum required by regulations),
- a back-up cabin crew member.

[9] Of which 591 flying hours on Airbus A340 and 216 hours on Airbus A330.

[10] Safety and rescue manual, section on A330/A340 airplanes, General airplane, general data – 1.20.30 p.1

1.5.2.1 Senior flight attendant

Female, aged 49

- Safety and emergency procedures (SEP) certificate obtained 19 July 1985
- Airbus A330/A340 familiarisation training course 1st August 1995
- General recurrent training 22 October 2008
- Recurrent Airbus A330/A340 training 27 November 2008
- Physical and mental aptitude check-up 11 June 2008
- Experience: 8,649 flying hours, including 2,073 on A330/A340

1.5.2.2 Purser

Female, aged 54

- Safety and emergency procedures (SEP) certificate obtained 10 July 1981
- Airbus A330/A340 adaptation training course 6 June 1997
- General recurrent training 16 October 2008
- Recurrent Airbus A330/A340 training 4 November 2008
- Physical and mental aptitude check-up 17 February 2009
- Experience: 6,704 flying hours, including 2,353 on Airbus A330/A340

1.5.2.3 Purser

Female, aged 45

- Safety and emergency procedures (SEP) certificate obtained 18 September 1989
- Airbus A330/A340 adaptation training course 18 December 2003
- General recurrent training 11 March 2009
- Recurrent Airbus A330/A340 training 13 March 2009
- Physical and mental aptitude check-up 17 February 2009
- Experience: 8,688 flying hours, including 1,241 on Airbus A330/A340

1.5.2.4 Flight attendants

Female, aged 44

- Safety and emergency procedures (SEP) certificate obtained 16 September 1991
- General recurrent training 19 January 2009
- Physical and mental aptitude check-up 17 December 2007
- Experience: 2,142 flying hours, including 510 on Airbus A330/A340

Note: not fully qualified on Airbus A330/A340.

Female, aged 38

- Safety and emergency procedures (SEP) certificate obtained 20 August 1996
- Airbus A330/A340 adaptation training course 28 March 2003
- General recurrent training 6 August 2008
- Recurrent Airbus A330/A340 training 30 September 2008
- Physical and mental aptitude check-up 1 August 2008
- Experience : 6,236 flying hours, including 1,160 on Airbus A330/A340

Male, aged 33

- ❐ Safety and emergency procedures (SEP) certificate obtained 9 March 1998
- ❐ Airbus A330/A340 adaptation training course 21 June 1999
- ❐ General recurrent training 16 October 2008
- ❐ Recurrent Airbus A330/A340 training 30 March 2009
- ❐ Physical and mental aptitude check-up 25 June 2007
- ❐ Experience: 8,098 flying hours, including 2,091 on Airbus A330/A340

Female, aged 31

- ❐ Safety and emergency procedures (SEP) certificate obtained 5 June 2001
- ❐ Airbus A330/A340 adaptation training course 5 March 2001
- ❐ General recurrent training 2 October 2008
- ❐ Recurrent Airbus A330/A340 training 16 December 2008
- ❐ Physical and mental aptitude check-up 2 May 2008
- ❐ Experience: 5,154 flying hours, including 1,047 on Airbus A330/A340

Female, aged 31

- ❐ Safety and emergency procedures (SEP) certificate obtained 21 July 2004
- ❐ General recurrent training 21 August 2008
- ❐ Physical and mental aptitude check-up 5 November 2007
- ❐ Experience: 3,137 flying hours, of which 662 on Airbus A330/A340

Note: not fully qualified on Airbus A330/A340.

Male, aged 23

- ❐ Initial back-up cabin crew member training course on 22 October 2007
- ❐ Recurrent back-up cabin crew member training on 26 August 2008
- ❐ Physical and mental aptitude check-up 14 June 2007
- ❐ Experience: 873 flying hours, of which 222 on Airbus A330/A340

Note: not an SEP holder.

1.6 Aircraft Information

Air France had owned the aircraft since April 2005. It had been delivered new.

1.6.1 Airframe

Manufacturer	Airbus
Type	A330-203
Serial number	0660
Registration	F-GZCP
Entry into service	April 2005
Certificate of Airworthiness	N°122424/1 dated 18 April 2005 issued by the DGAC
Airworthiness examination certificate	2009/122424/1 valid until 17/4/2010
Utilisation as of 31 May 2009	18,870 flying hours and 2,644 cycles

1.6.2 Engines

Manufacturer: General Electric

Type: CF6-80-E1A3

	Engine No. 1	Engine No. 2
Serial number	811296	811297
Installation date	1/10/2004	1/10/2004
Total running time	18,870 hours and 2,644 cycles	18,870 hours and 2,644 cycles

The engines were subject to real-time monitoring in the framework of the engine condition monitoring program. Examination of the data recorded, including the data transmitted on the day of the accident, shows that both engines were functioning normally.

1.6.3 Weight and balance

The aircraft left the gate with a calculated weight of 233,257 kg. The estimated takeoff weight was 232,757 kg(11), for a maximum authorised takeoff weight of 233 t. This takeoff weight broke down as follows:

- empty weight in operating condition: 126,010 kg,
- passenger weight: 17,615 kg (126 men, 82 women, 7 children and one baby(12)),
- weight in cargo compartment (freight and luggage): 18,732 kg,
- fuel weight: 70,400 kg.

The on-board fuel weight corresponded to forecast trip fuel of 63,900 kg, route factor fuel of 1,460 kg, final reserve of 2,200 kg, fuel to alternate airport reserve of 1,900 kg and 940 kg additional fuel. An LMC corrected the definitive load sheet to take into account one passenger less without baggage.

The balance corresponding to the aircraft's takeoff weight and given on the definitive load sheet (after LMC) was 23.3% of the MAC, for a forward limit of 22.7% and an aft limit of 36.2% at takeoff.

On the basis of the operational flight plan, it is possible to estimate the trip fuel at 27.8 t after a flying time of 3 h 41 min(13), the aircraft would then have had an estimated weight of 205 t and balance comprised between 37.3% and 37.8%(14), which is within the limits of the operating envelope (Operating Manual TU page 12.28.10.9).

1.6.4 Condition of the aircraft before departure

On arrival of the Paris-Rio de Janeiro flight the day before the accident, the Captain reported a problem at the level of the VHF1 selection key on RMP1. The aircraft has three RMPs: RMP1 on the left-hand side, RMP2 on the right-hand side and RMP3 on the overhead panel. The ground engineer had switched round RMP1 and RMP3 to allow the aircraft to leave, in compliance with the regulations (departure covered by a MEL). The departure covered by this MEL item did not have any operational consequences.

(11) A quantity of 500 kg of fuel had been taken into account for taxiing between the ramp and takeoff brake-release.

(12) Air France applies a standard weight of 91 kg for a man, 72 kg for a woman and 35 kg for a child, which is compatible with the European regulations.

(13) Which corresponds to the middle of the ORARO – TASIL segment.

(14) This type of aircraft is equipped with a fuel management system (FCMS) that controls the transfer of fuel to and from the "trim tank". This transfer, which begins as soon as the aircraft starts to climb, makes it possible to reduce drag and therefore fuel consumption by shifting the aircraft's centre of gravity. The centre of gravity target is controlled to within 0.5% of MAC.

1.6.5 Maintenance operations follow-up

Daily and weekly checks are carried out. They make it possible to perform preventive maintenance tasks and correct any problems reported after flights by the crew.

Type A checks, on the Airbus A330, are carried out every 800 flying hours, which represents a check every two months approximately for an airline such as Air France. This check consists of:

- checking the systems by means of operational tests,
- performing greasing and lubrication operations,
- carrying out various checks on the oil and hydraulic fluid levels,
- visually inspecting the structural parts, without removal.

The last three checks of this type were performed on F-GZCP on 27 December 2008, 21 February 2009 and 16 April 2009.

These checks were performed in accordance with the operator's maintenance programme, drawn up on the basis of the manufacturer's recommendations and approved by the national authorities who are also responsible for oversight.

Examination of these maintenance documents, of the maintenance programme and of the aircraft's airworthiness dossier did not reveal any anomalies.

1.6.6 Information on the airspeed measuring system

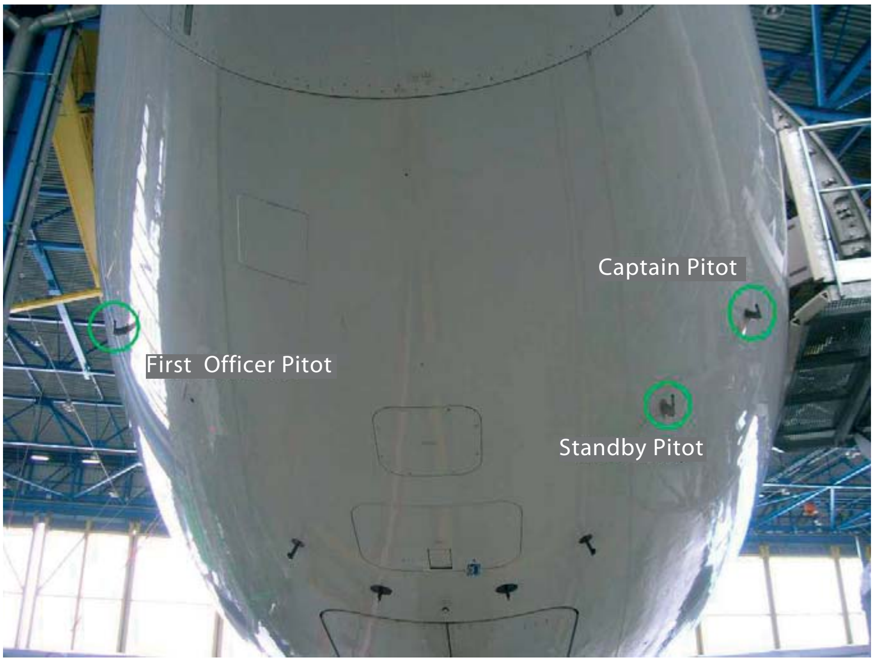
1.6.6.1 Elaboration of the speed information

The speed is deduced from the measurement of two pressures:

- total pressure (Pt), by means of an instrument called a Pitot probe,
- static pressure (Ps), by means of a static pressure pick-off.

Probes

The Airbus A330 has three Pitot probes (see hereafter) and six static pressure pick-offs. These probes are fitted with drains allowing the removal of water, and with an electrical heating system designed to prevent them from icing up.



Position of the Pitot probes on the Airbus A330

Pitot probe (with protection caps)

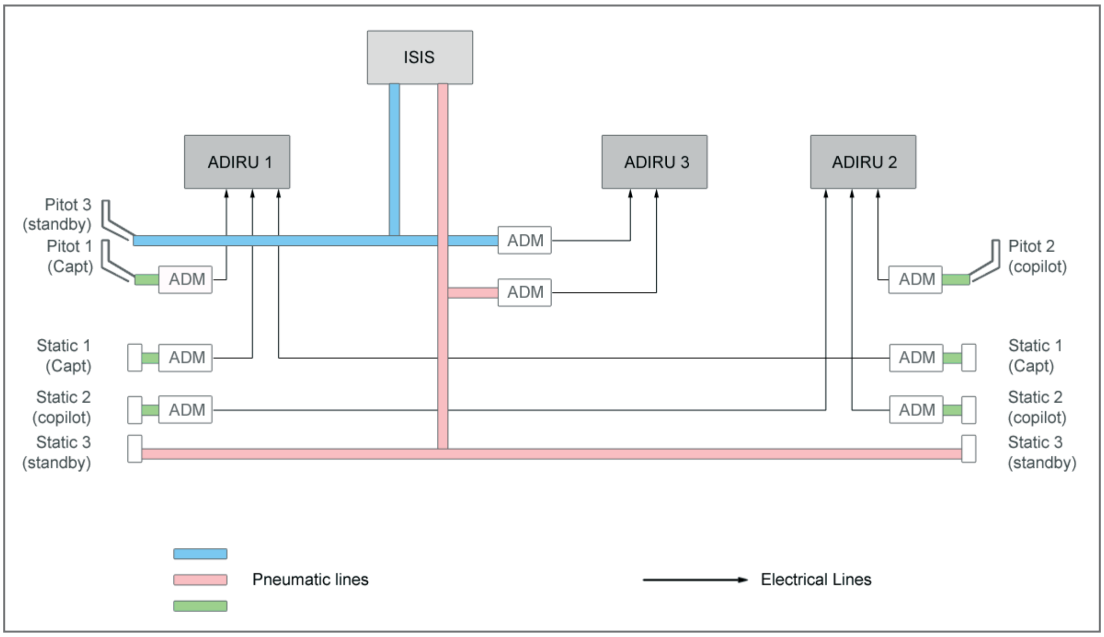
The pneumatic measurements are converted into electrical signals by eight ADMs and delivered to the calculators in that form.

Speed calculation by the ADR

The CAS and Mach number are the main items of speed information used by the pilots and the systems to control the aircraft. These parameters are elaborated by three calculators, called ADIRU, each consisting of:

- an ADR module which calculates the aerodynamic parameters, specifically the CAS and the Mach,
- an IR module that provides the parameters delivered by the inertial units, such as ground speed and attitudes.

The ADRs use the measured pressure values to calculate the CAS and the Mach. The diagram below shows in simplified form the overall architecture of the airspeed measuring system:



There are therefore three speed information elaboration systems that function independently of each other. The “Captain” probes feed ADR 1, the “First Officer” probes feed ADR 2 and the “Standby” probes feed ADR 3.

Only the standby instruments such as the ISIS elaborate their speed and altitude information directly from the pneumatic inputs (“standby” probes), without this being processed by an ADM or ADR.

1.6.6.2 Systems that use the speed information

The speeds calculated by the ADRs are used, in particular, by the following systems:

- fly-by-wire controls system,
- engine management system,
- flight management and guidance system,
- ground proximity warning system,
- transponder,
- slats and flaps control system.

1.6.7 Checks and maintenance of the Pitot probes

The Pitot probes and maintenance actions are described in the operator’s maintenance manual.

The Pitot probes are subject to a daily visual inspection by a mechanic, who checks their general condition. The crew performs the same type of check before each flight.

During Type C checks, the following operations are performed on the Pitot probes:

- cleaning of the complete probe using compressed air (“blowing” operation),
- cleaning of the drains with a specific tool,
- test and check of probe heating by the standby electrical power supply system,
- check of the sealing of the circuits.

In the case of speed inconsistencies being reported by the crew, corrective actions are the same as those in the Type C checks.

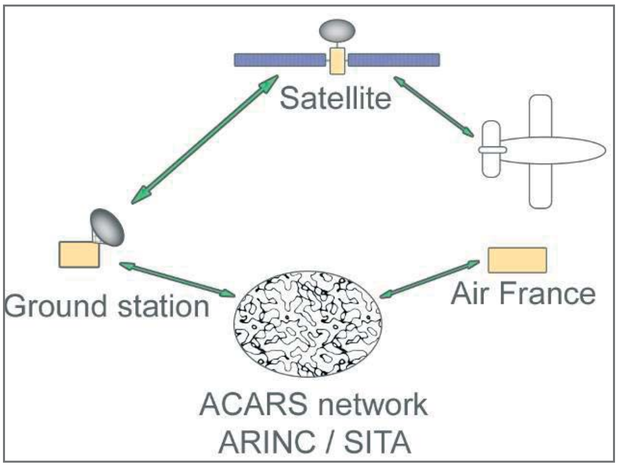
1.6.8 ACARS communication system

The ACARS system, integrated in the ATSU on Air France's Airbus A330, is used to transmit non-vocal messages between an aircraft and the ground by VHF or satellite communication. It can be used in particular by operators to transmit information in real time (meteorological data, flight progress information, etc.).

There are three major categories of message that can be transmitted:

- non-vocal (ATC) communication messages with an air traffic control centre (CPDLC in particular),
- operational communication messages (AOC) with the operator's operations centre,
- maintenance messages, exclusively from the aircraft to the maintenance centre.

ACARS messages are transmitted as a priority by VHF or by satellite if VHF is unavailable. They pass through an ACARS service provider's server (ARINC or SITA) before arriving at the operator's centre.



Information relative to the network (processing by the ground station and/or service provider's server) and information relative to the satellite (type of message, channel used, etc.) is added to the useful message.

The ATC and operational messages are generated by the ATSU. The maintenance messages are generated by the CMC and transferred to the ATSU before being transmitted. Of these three types of message, it is the ATC messages that have the highest priority.

Note: the operator can configure part of the ATSU (the AOC part in particular) so as to filter the maintenance messages transmitted or to send specific types of information relative to the flight.

F-GZCP was programmed to automatically transmit its position approximately every ten minutes.

1.6.9 Centralised Maintenance System

The aircraft has a Centralised Maintenance System (CMS) whose role is to facilitate maintenance operations. It acquires and saves certain messages transmitted by the Flight Warning System (FWS) or the test functions integrated in the systems (BITE). It generates maintenance reports, including the CFRs (when the aircraft is in flight) and PFRs (once the aircraft has landed).

The CMS groups together two Central Maintenance Calculators (CMC) and the various systems' integrated test functions.

1.6.9.1 Flight Reports (CFR and PFR)

The CFR is made up of all the maintenance messages generated on-board an aircraft in flight. Once on the ground, the system generates a more elaborate report, called the PFR.

A maintenance-related message may be:

- a fault message reflecting the triggering of a monitoring process which may inform on the status or functioning of the system concerned,
- a cockpit effect message reflecting an indication presented in the cockpit (for example an ECAM message or a flag).

Note: the term 'fault' means the triggering of a monitoring process that may, in certain cases, refer to a failure.

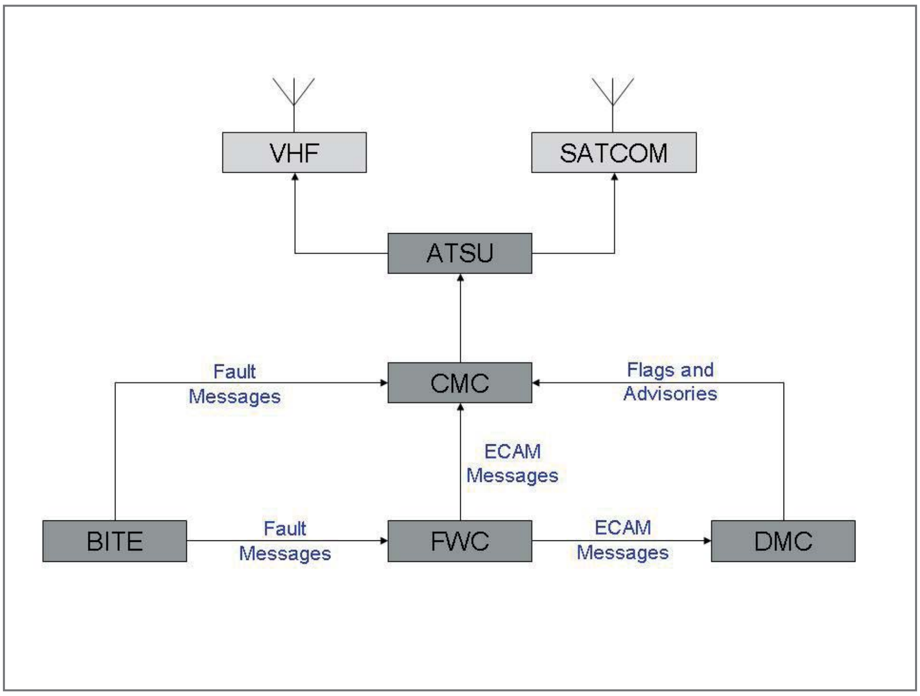
There are three classes of fault messages:

- class 1: these have operational consequences and are accompanied by at least one cockpit effect (not necessarily recorded in the CFR),
- class 2: these do not have any operational consequences; they are accompanied by one or more "MAINTENANCE STATUS" messages that are only brought to the attention of the crew via the ECAM's STATUS page once on the ground,
- class 3: these messages can only be consulted on the ground, by using each calculator's BITE systems; these messages are therefore not included in the CFR or PFR.

Unlike the CFR, the PFR presents correlations between the fault and cockpit effect messages. The relative positions of the messages in a CFR and in the corresponding PFR may therefore be different.

1.6.9.2 Maintenance message acquisition by the CMC

The CMC acquires certain ECAM messages from the FWC, in the order that the latter transmits them. This is not necessarily the order in which those messages were displayed on the Engine Warning Display (E/WD). Up to one hundred messages can be acquired in one second. The messages indicating a flag or an advisory are received from the DMCs and must be confirmed for between 2.4 and 3 seconds in order to be acquired. They are timed once this confirmation has been made.



The fault messages are received from the BITE of the various systems. When a system detects a fault, it transmits a fault message to the CMC containing:

- the ATA code (six digits) of the equipment concerned by the fault,
- the name of the system that detected the problem, called the source,
- the message's class (1 or 2),
- a message describing the fault,
- information on whether the fault is of a lasting ("HARD") nature or not ("INTERMITTENT").

When the CMC receives this type of message, it opens a one-minute correlation window corresponding to the first three or four digits of the ATA code. During this period, all the fault messages that may have been received including those same three or four first ATA code digits are grouped together. Once the minute has elapsed, the CMC closes the correlation window and applies the priority rules between the correlated messages in order to generate an overall message:

- class 3 messages are not taken into account,
- a class 1 message takes priority over a class 2 message,
- for two messages of the same class, a message reporting an internal fault (the system detects a fault in its own operation) takes priority over one reporting an external fault (the system observes a fault in another system),
- and as a last resort, the oldest message takes priority.

The overall message generated then contains the priority message's information (ATA code, source, etc.), to which is added the list of names of the other systems called identifiers that have generated correlated messages.

It is this overall message that then appears in the CFR or PFR. So, no information on the descriptions of the messages transmitted by the identifiers is given; only the description of the priority message is saved. Furthermore, if the source or one of the identifiers has transmitted a class 2 message, its name is preceded by an asterisk (*). The following theoretical sequence is given as an example:

Time	Fault message	Change in the overall message at each stage
T0	"**message 1**" Class 2 Source: SYS1	"**message 1**" Class 2 Source : SYS1 Identifiers: -
T0+5 s	"**message 2**" Class 1 Source: SYS2 External fault	"**message 2**" Class 1 Source: SYS2 Identifiers: *SYS1
T0+10 s	"**message 3**" Class 1 Source: SYS3 Internal fault	"**message 3**" Class 1 Source: SYS3 Identifiers: SYS2,*SYS1
T0+59 s	"**message 4**" Class 2 Source : SYS3	"**message 3**" Class 1 Source: *SYS3 Identifiers: SYS2,*SYS1
T0+1 min	Closing of the correlation window. Generation of the **overall message**.	

All the messages are timed to the nearest minute. The timing of an ECAM message consists of the time of its acquisition by the CMC, and that of a fault message is the time at which the correlation window opened. It is therefore possible in a CFR to find an ECAM message preceding a fault message that is nevertheless timed one minute before it. So, for example:

Occurrence time	Message	CFR
hh:10:10	"**message 1**" ***fault***	Opening of a correlation window
hh:10:15	"**message 2**" ***ECAM***	**ECAM message dated hh10**
hh:11:05	"**message 3**" ***ECAM***	**ECAM message dated hh11**
hh:11:10	End of the "**message 1**" correlation window	**Fault message dated hh10**

1.6.9.3 Transmission of maintenance messages by the CMC

In order to transmit the messages by ACARS, the CMC sends them to the ATSU. ECAM messages are transmitted in real time as soon as they are acquired. Flag or advisory messages are transmitted as soon as they have been confirmed. Fault messages are transmitted as soon as the corresponding correlation window is closed.

1.6.10 Radio communications system

The Airbus A330's radio communications system consists of the following equipment:

- ❐ VHF and HF transmitters-receivers
- ❐ RMPs,
- ❐ audio integration systems: ACP and AMU.

Each VHF / HF transmitter-receiver can be controlled by one of the three RMPs.

1.6.10.1 VHF equipment

There are three identical VHF communication systems installed. Each system includes:

- ❐ a transmitter-receiver in the avionics compartment,
- ❐ an antenna on the upper part of the fuselage for VHF 1 and VHF 3, and on the lower part of the fuselage for VHF 2.

1.6.10.2 HF equipment

The aircraft has two HF communication systems. Each system includes:

- ❐ a transmitter-receiver in the avionics compartment,
- ❐ an antenna coupler situated at the root of the stabiliser,
- ❐ a shared antenna integrated in the leading edge of the fin.

Since the HF system has a range of several thousand kilometres, a large number of communications are received. Furthermore, the quality of the transmissions may sometimes be poor. Communications may also be interrupted due to natural phenomena.

A SELCAL call system, transmitting a light and sound signal, informs the crew when a ground station is attempting to contact them.

1.7 Meteorological Conditions

1.7.1 Meteorological Situation

Appendix 1 contains the complete detailed study supplied by Météo France.

From a climatology point of view, the general conditions and the position of the Inter-tropical Convergence Zone over the Atlantic were normal for the month of June. Cumulonimbus clusters that are characteristic of this zone were present, with a significant spatial heterogeneity and lifespan of a few hours.

Infra-red images taken every fifteen minutes by the geostationary satellite Meteosat 9 are the best source of information at this stage to appreciate the evolution of these clusters, but they did make it possible to directly observe the conditions encountered at FL350. Moreover, the two most representative images were taken approximately seven minutes before and after the last ACARS message from flight AF447.

The infra-red imagery analysis does not make it possible to conclude that the stormy activity in the zone where flight AF447 is presumed to have disappeared was exceptional in character, but it shows the existence of a cluster of powerful cumulonimbi along the planned flight path, identifiable from 00 h 30 onwards. This cluster was the result of the fusion of four smaller clusters and its east-west extension was approximately 400 km.

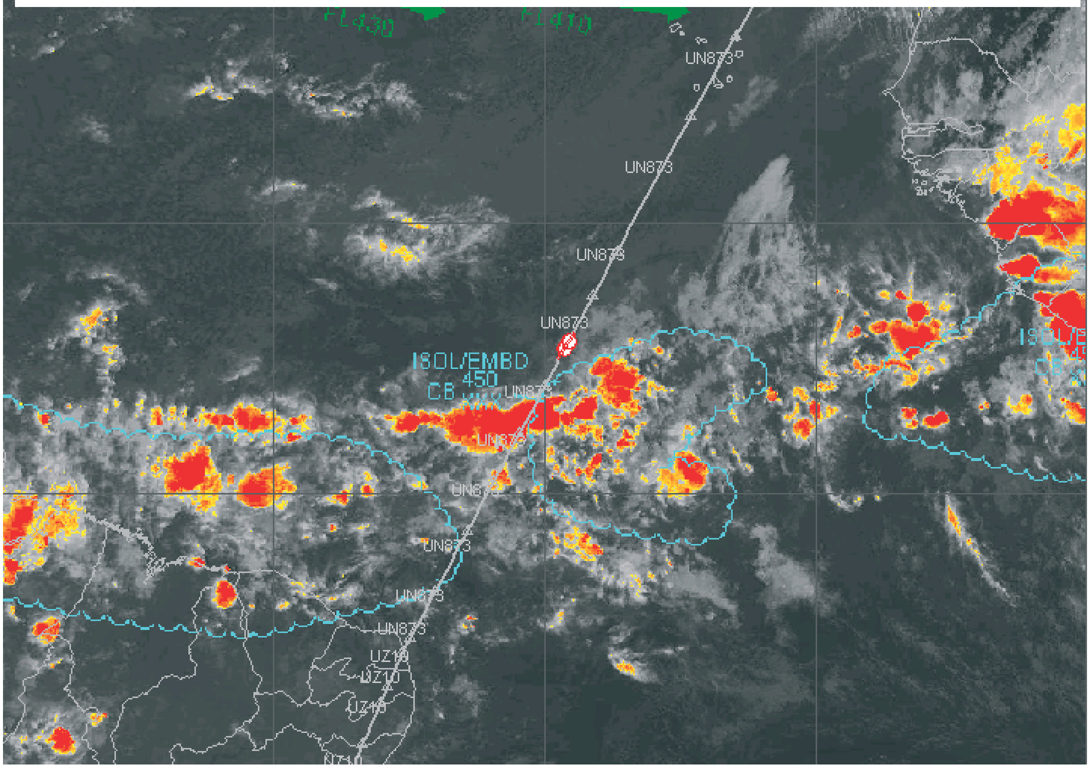
Though the analysis of the imagery leads one to think that, towards 2 h 00, the cumulonimbi forming this cluster had mostly already reached their stage of maturity, it is highly probable that some were the site of notable turbulence at FL350. There is a possibility of significant electrical activity at the flight level, but the presence of super cooled water at FL350 is not very probable and would necessarily have been limited to small quantities.

1.7.2 Comments on the information available

1.7.2.1 Forecast charts

The TEMSI chart for 00 h 00 (Appendix 2) shows that the planned route touches the two East-West oriented cloudy masses, located on both sides of the equator and mentions: ISOL/EMBD CB between levels XXX (base located below FL250) and FL450. The highest altitude of the tropopause along the route is estimated at FL500. A 280°/85 kt jet stream is indicated around the 10° North parallel, to the West of the route, at FL410 and FL430. The following illustration shows the superimposition of this TEMSI with the infra-red image for 00 h 00.

IR -40° 1st June 00 h 00 + extract TMSI London 1st June 00 h



Note: the TEMSI charts and the wind and temperature charts are forecasts based on a digital model at a synoptic scale produced 24 hours before a specific validity time, for the South America region. These charts present the large convective activity zones in the area described but do not indicate the specific position of the cumulonimbi and the cumulonimbus clusters.

The wind and temperature charts show that the average effective wind along the route can be estimated at approximately ten knots tail-wind. On the chart for FL340, the highest air temperature is located around the equator. It is estimated at – 40 °C, that is to say, Standard + 13 °C.

The CAT charts do not forecast any clear air turbulence along the route.

1.7.2.2 SIGMET

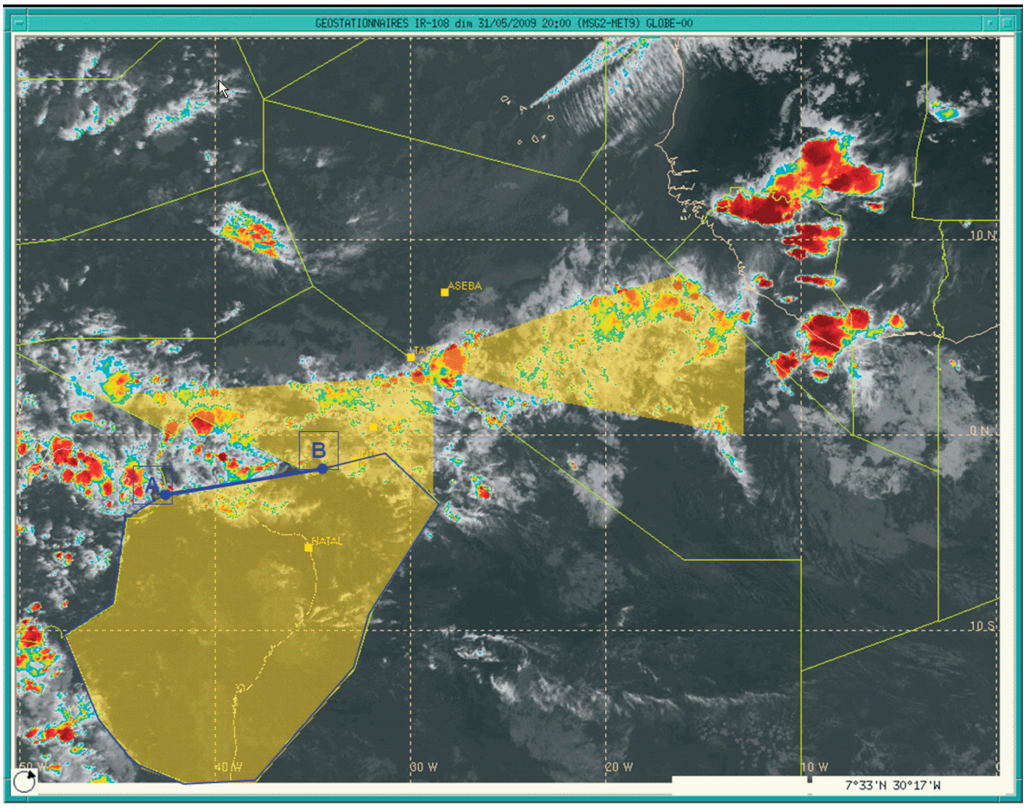
SIGMET 5 issued for the RECIFE FIR on May 31 at 17 h 58, valid from 18 h 00 to 22 h 00, reported a storm forecast in the layer with tops at FL350.

SIGMET 7, issued for the ATLANTICO FIR on May 31 at 17 h 58, valid from 18 h 00 to 22 h 00, reported a storm forecast in the layer with tops at FL370.

SIGMET 7, issued for the DAKAR FIR on May 31 at 16 h 33, valid from 16 h 35 to 20 h 35, reported the observation of isolated storms in the layer, with tops at FL450, moving towards the west at 10 kt.

The zones covered by these messages are shown in the following image, superimposed on the Meteosat 9 infra-red image for 20 h 00.

Note: crews do not have access to such a view.



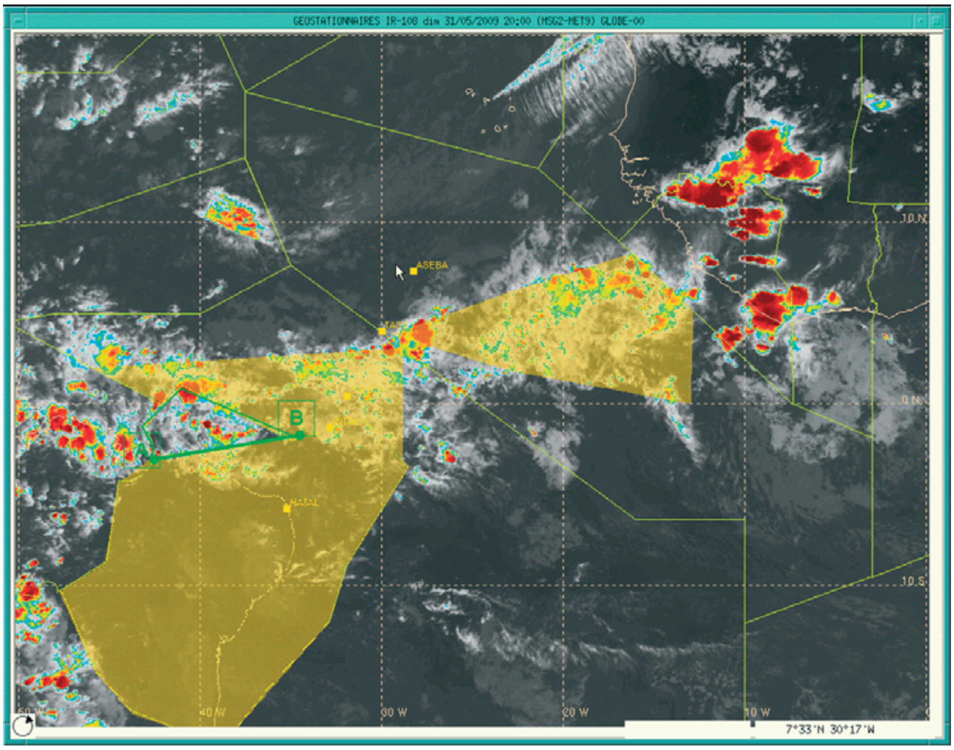
SIGMET 5 issued for the RECIFE FIR defines the zone affected by storms as being to the south-west of line AB shown in the figure above. This SIGMET reads as follows:

WSBZ31 SBRE 311752 SBRE SIGMET 5 VALID 311800/312200 SBRE-RECIFE FIR EMBD TS FCST SW OF CLARK PSN/ PEPER PSN/ NEURA PSN AREA TOP FL350 STNR NC=

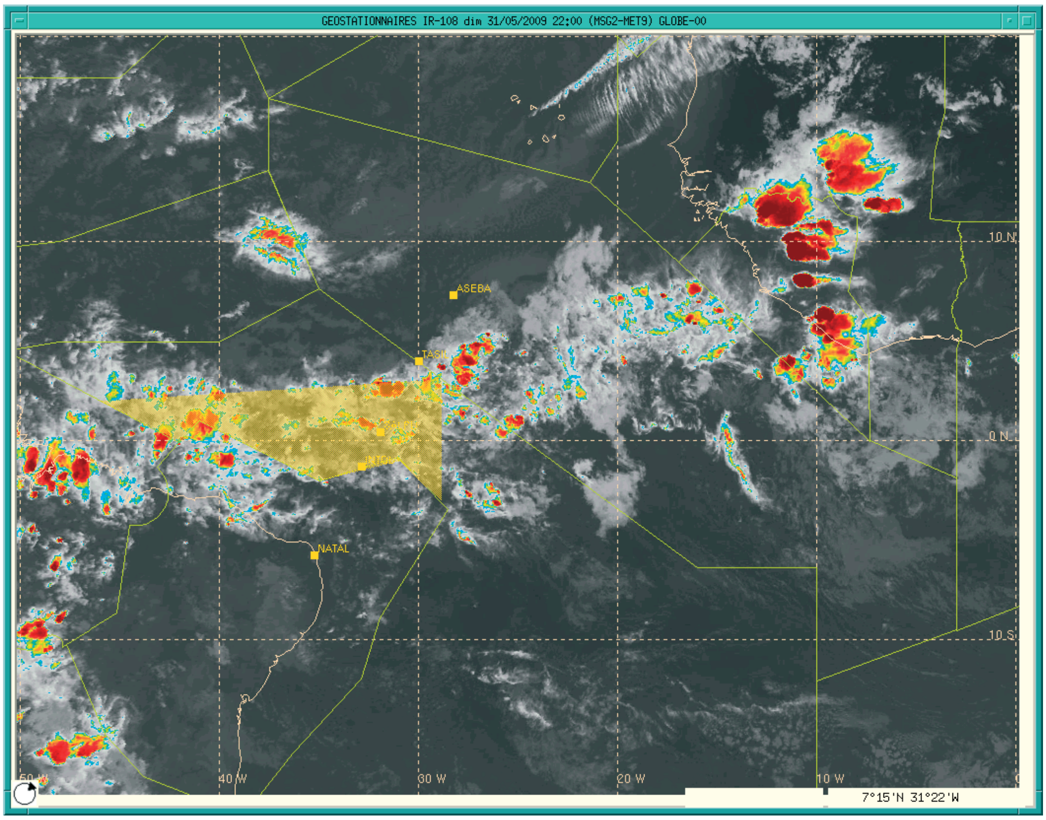
The validity of this message is questionable for two reasons:

- line AB is in the south-west/north-east direction and yet, in such a case, a "SE OF" or "NE NW OF" mention would be expected, and not "SW OF" as is the case in the SIGMET,
- the satellite images during the period of validity of the SIGMET show the convection zone to be located to the North-West of line AB rather than to the South-East of the same.

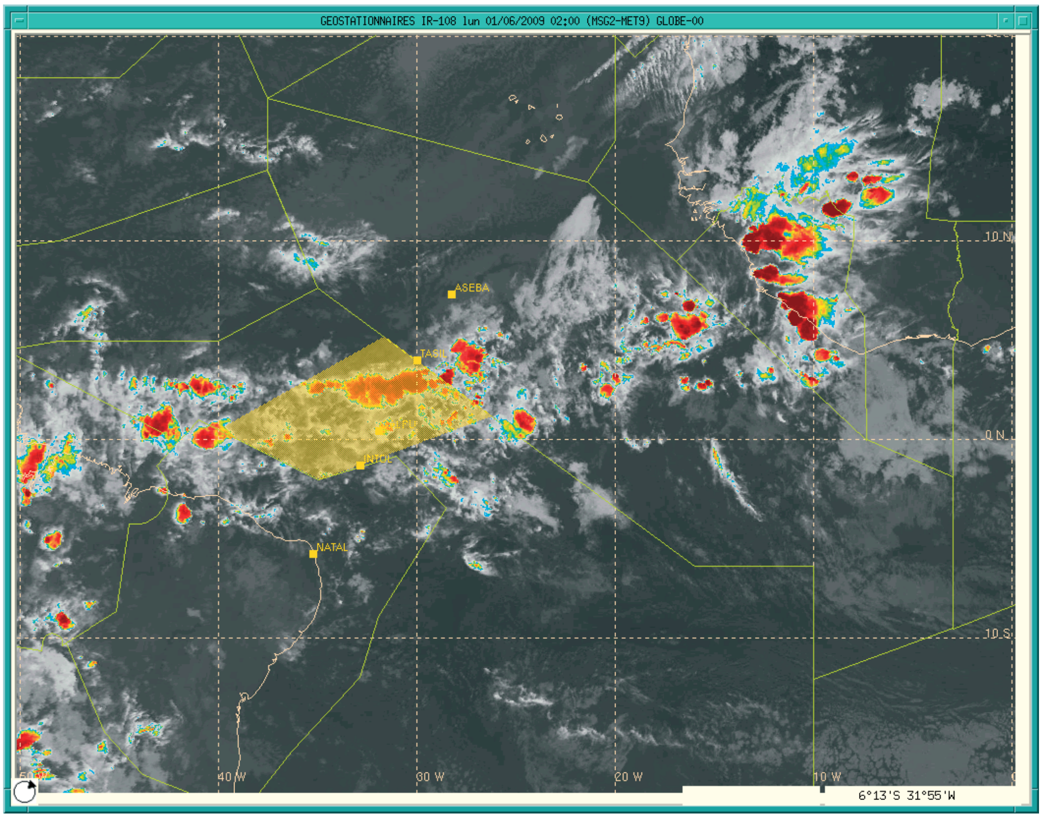
It is thus possible that this SIGMET includes an error, with a SW OF mention instead of a NW OF mention. On this assumption, SIGMET 5 SBRE would complete the zone identified in the ATLANTICO FIR, as represented by the green line in the figure below:



SIGMET 10 was then issued for the ATLANTICO FIR for the period from 31 May at 22 h 00 to 1st June at 2 h 00, reporting a forecast of stationary storms in the layer, with tops at FL400. The zone covered is illustrated hereafter:



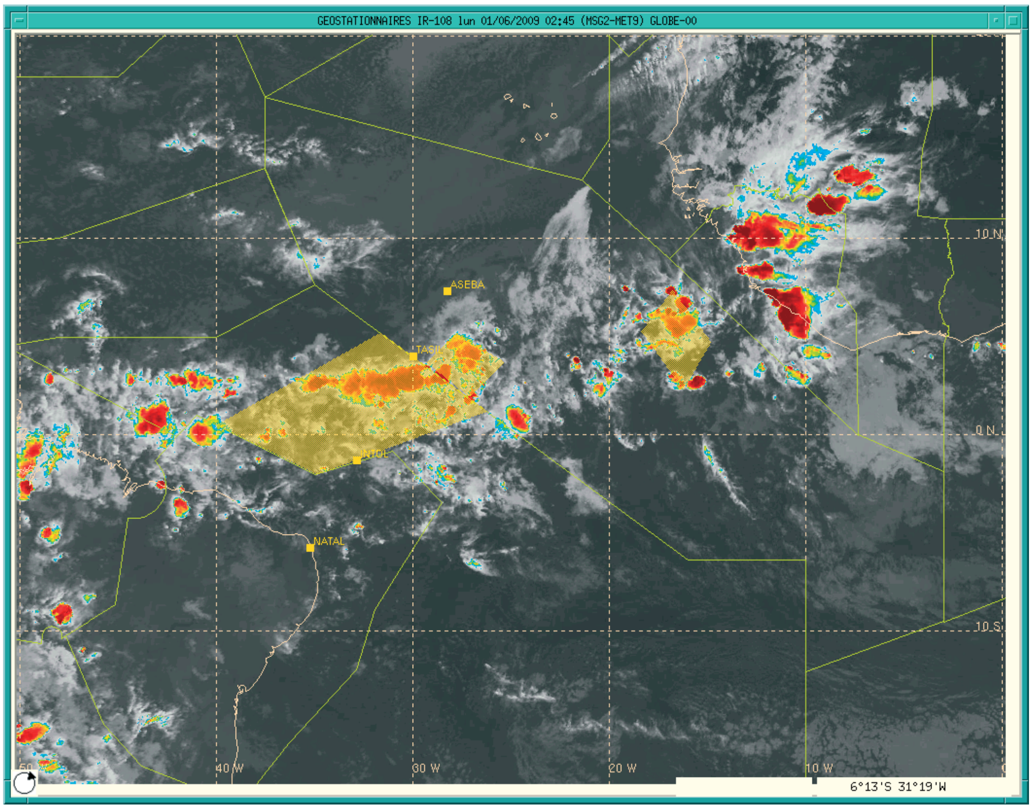
SIGMET 1 issued on 1st June for the ATLANTICO FIR, valid between 2 h 00 and 6 h 00, reported forecast stationary storms in the layer, with tops at FL380. The zone covered is illustrated hereafter:



SIGMET 2 issued for the DAKAR FIR on 1st June at 2 h 44, valid from 2 h 45 to 6 h 45, reported storms observed in the layer at 2 h 15 whose tops were at FL450.

Note: in this SIGMET, the point referenced N 05°15'- W 072°49' is probably N 05°15' - W 027°49'.

The zone covered by these two SIGMETs is illustrated below.



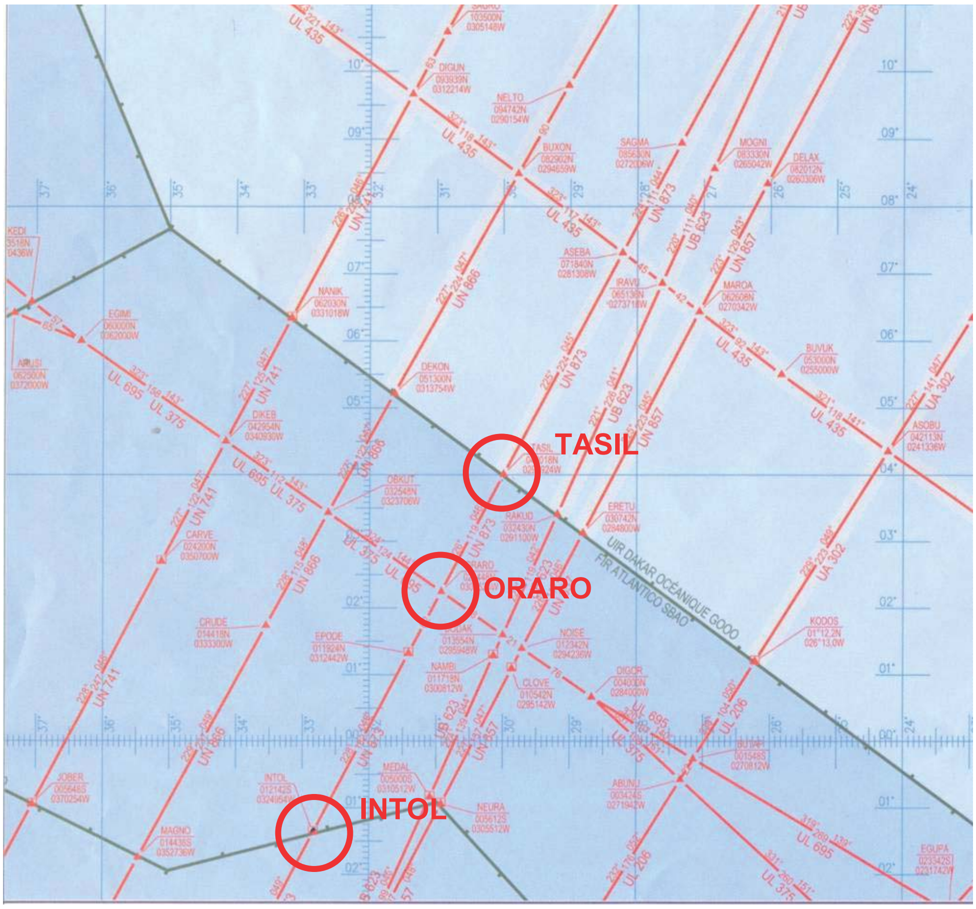
1.8 Aids to Navigation

The GNSS is the only navigation aid near the TASIL point.

At the estimated time of the event, the GPS constellation offered the navigation precision required on the route.

1.9 Communications

Transcripts of the radio communications relating to flight AF447, provided by Brazil, are in appendix 3.



1.9.1 Communications between the control centres

Note: the times mentioned come from the transcripts made by the Brazilian authority. There is a variation of about one minute between this reference and that of the Senegalese ATC.

Between 21 h 40 and 23 h 18, the crew successively communicated:

- on the Rio de Janeiro "clearance" frequency (121.0 MHz) at 21 h 40,
- on the ground controller frequency (121.65 MHz), control tower frequency (118.2 MHz), and departure control frequency (128.9 MHz),
- on the CURITIBA FIR frequency (133.4 MHz or 133.6 MHz). The CURITIBA controller cleared the flight to climb to FL350,
- on the BRASILIA frequency (126.55 MHz, then 125.45 MHz and 128.7 MHz).

At 23 h 18 min 37, it was transferred to the RECIFE frequency (126.5 MHz).

At 0 h 36 min 40, the RECIFE controller asked it to maintain the altitude of FL350 and to contact ATLANTICO on HF (6535 or 5565 kHz) when passing the INTOL point.

At 1 h 31 min 44, the RECIFE controller gave it the ATLANTICO HF frequencies: 6649 or 5565 kHz, then 6535 kHz after the TASIL point. The crew read back the three frequencies.

Note: TASIL is on the boundary between the ATLANTICO and DAKAR Oceanic FIRs.

At 1 h 33 min 25, the crew contacted the ATLANTICO controller on the 6649 kHz frequency. At 1 35 min 15, they informed the controller that they had passed the INTOL point at 1 h 33, at FL350. They announced the following estimates: SALPU at 1 h 48 then ORARO at 2. They also transmitted their SELCAL code: CPHQ.

At 1 h 35 min 26, the ATLANTICO controller coordinated flight AF447 with the DAKAR controller. At 1 35 min 32, the ATLANTICO controller transmitted the following items to the DAKAR controller: TASIL estimated at 2 h 20, FL350, Mach 0.82.

At 1 h 35 min 38, the ATLANTICO controller sent a SELCAL call.

At 1 h 35 min 43, the crew thanked the controller.

At 1 h 35 min 46, the controller asked them to maintain an altitude of FL350 and to give a TASIL estimate.

Between 1 h 35 min 53 and 1 h 36 min 14, the ATLANTICO controller asked the crew three times for their estimated time passing the TASIL point. The crew did not answer.

1.9.2 Coordination between the control centres

Note: the times mentioned come from the transcripts made by the Senegalese authority. There is a variation of about one minute between this reference and that of the Brazilian ATC.

At 1 h 46, the DAKAR controller asked the ATLANTICO controller for further information regarding flight AF447 since he had no flight plan. The ATLANTICO controller provided the following elements: A332, from SBGL to LFPG, SELCAL: CPHQ.

The DAKAR OCEANIC Regional Control Centre created the flight plan and activated it. The result of this was to generate a virtual flight following the planned trajectory in the DAKAR FIR between TASIL and POMAT. There was no radio contact between AF447 and DAKAR, nor any ADS-C connection. The flight remained virtual.

At 2 h 47 min 00, the DAKAR controller coordinated flight AF447 by telephone (ATS/DS) with the SAL controller (Cape Verde) with the following information: passing the POMAT point (leaving the DAKAR FIR) estimated at 3 h 45, FL350, Mach 0.82.

At 2 h 48 min 07, the DAKAR controller told the SAL controller that flight AF447 had not yet established contact with him.

At 3 h 54 min 30, the SAL controller called the DAKAR controller by telephone (ATS/DS) to confirm the estimated time for passing the POMAT point. The latter confirmed that POMAT was estimated at 3 h 45. The DAKAR controller stated that the crew of flight AF447 had not contacted him to correct its estimate. The SAL controller replied that the estimate was probably later. He asked the DAKAR controller if there was any change. The DAKAR controller then said that he was going to try to contact flight AF447.

At 4 h 07 min 04, the SAL controller requested confirmation of the flight AF447 estimate. The DAKAR controller confirmed again that POMAT was estimated at 3 h 45. The SAL controller pointed out that it was 4 h 8 and that the estimate was not correct. The DAKAR controller recalled that contact had not been established with flight AF447. The SAL controller stated that he had identified flight AF459 on his radar whereas its estimate was later than that of flight AF447. The SAL controller said that he thought that the POMAT estimate was later, at 4 h 29 or 4 h 30. The Dakar controller told the SAL controller that he would call him back.

At 4 h 11 min 53, the DAKAR controller asked flight AF459 to contact flight AF447.

At 4 h 20 min 27, the crew of AF459 informed the DAKAR controller that they were passing point POMAT at FL370. They had not succeeded in contacting flight AF447 and said that they had sent a message to Air France so that the airline should try to contact flight AF447.

At 4 h 20 min 36, the DAKAR controller asked the crew of AF459 to contact SAL on the 128.3 MHz frequency.

At 4 h 21 min 52, the DAKAR controller asked the ATLANTICO controller to confirm that flight AF447 had passed TASIL at 2 h 20 at FL350. The ATLANTICO controller confirmed that TASIL was estimated at 2 h 20 but that no contact had been made.

The DAKAR controller confirmed to the SAL controller that he still had no radio contact with the plane and that the estimates were correct.

At 4 h 37 min 07, the DAKAR controller asked the SAL controller if he had still not been able to contact flight AF447 and informed him that, according to the ATLANTICO controller, the flight should have left the FIR at 2 h 20 and consequently the POMAT estimate should be 3 h 45.

At 4 h 39 min 42, the DAKAR controller asked the ATLANTICO controller to confirm that he had not had contact with flight AF447. The latter replied that he had not had contact at TASIL but that the first contact was at INTOL at 1 h 33. The DAKAR controller told the ATLANTICO controller that SAL had not established contact either. The ATLANTICO controller said that he would call back later.

At 4 h 52 min 36, the DAKAR controller called the SAL controller again to ask him whether he had established contact. He confirmed the estimates at the boundaries of the FIR and asked the SAL controller to call him back if he established contact.

At 4 h 53 min 50, the ATLANTICO controller called the DAKAR controller again. He told him that he would check the estimates again and call him back.

At 5 h 01 min 34, the DAKAR controller asked the CANARIAS controller if he was in contact with AF447. The latter replied that he had no information.

At 5 h 06 min 17, the SAL controller asked the DAKAR controller if he had a position report for flight AF447 at the boundary with the ATLANTICO FIR. The latter replied that he had not.

At 5 h 09 min 15, the ATLANTICO controller asked the DAKAR controller if he had any news of flight AF447. The DAKAR controller replied that he hadn't and

then the ATLANTICO controller requested confirmation that the flight was already in the SAL FIR. The DAKAR controller replied: "yes, no worry". He also confirmed that SAL had not established contact with flight AF447.

The continuation of the exchanges between the control centres is described in paragraph 1.15.

1.10 Aerodrome Information

The support aerodromes for this ETOPS 120 minute flight were: Natal (Brazil) and Sal Amilcar (Cape Verde).

1.11 Flight Recorders

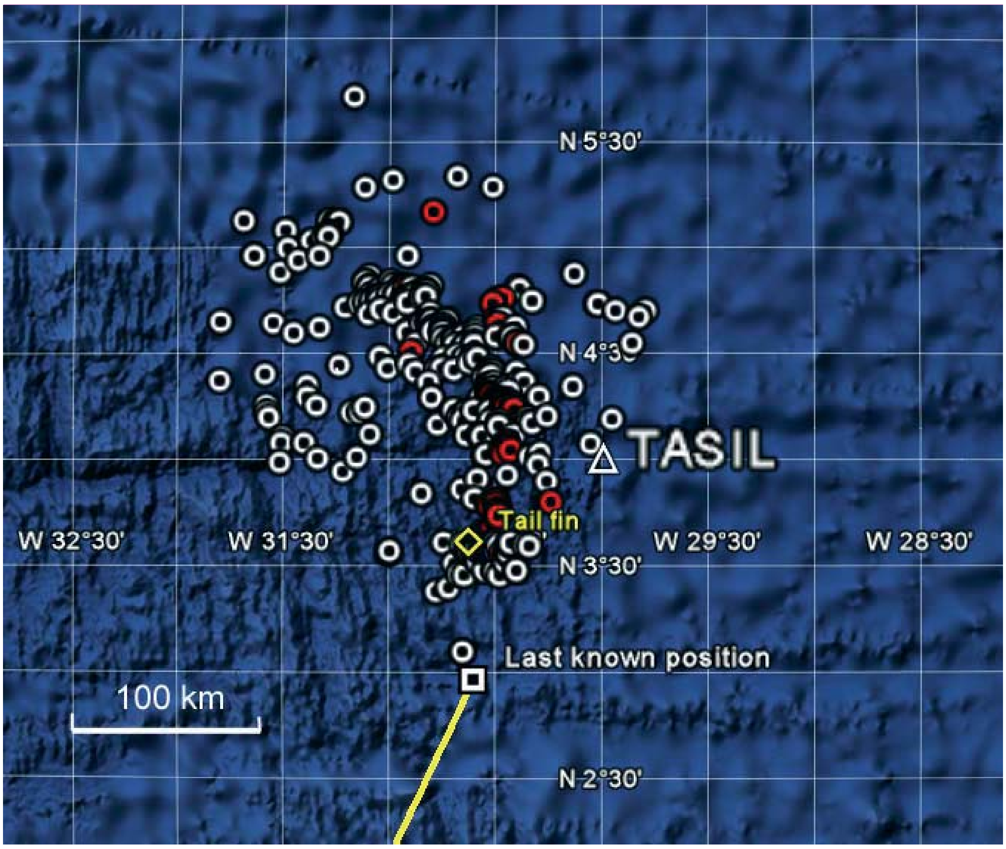
At the time of writing of this report, search operations were still under way to try to locate and recover the Flight Data Recorder and Cockpit Voice Recorder.

1.12 Wreckage and Impact Information

1.12.1 Localisation of the bodies and aircraft parts

The French and Brazilian navies found debris belonging to the aircraft from 6 June onwards. All the debris known to the BEA was referenced in a database. By 26 June, this database included 640 items.

Whenever the information is available, the position, the date and the time of their recovery are indicated. The chart below shows the position of all of the bodies and debris thus geo-referenced. The bodies are represented by red circles and the debris by white circles. The tail fin (vertical stabiliser), found on 7 June is represented by a yellow diamond.



The timeline of the recovery of the bodies and debris from the aircraft found between 6 June and 18 June, 2009 and known to the BEA on 26 June, 2009, can be found in appendix 4.

1.12.2 Identification of the items recovered

The identification of the debris shows that it consists mainly of light items belonging to the cabin fittings and holds (bulkheads, galley, ceiling or floor panels, seats, overhead baggage bins, cabin and hold lining).

Approximately thirty pieces are external parts of the plane (vertical stabiliser, pieces of the radome, the engine cowl, the under belly fairing, the flap actuator fairing, the trimmable horizontal stabiliser and the secondary control surfaces).

The identified debris thus comes from all the areas of the plane.

An ELT distress beacon with manual tripping was also recovered. This had not been actuated. Its switch was found in the "OFF" position.

1.12.3 Visual inspection

A first visual inspection brought to light the following.

The tail fin was damaged during its recovery and transport but the photographs available made it possible to identify the damage that was not the result of the accident. The middle and rear fasteners with the related fragments of the fuselage hoop frames were present in the fin base. The distortions of the frames showed that they broke during a forward motion with a slight twisting component towards the left.

Part of the radome was found, representing approximately a fifth of its circumference along its upper part.

The galley, identified as G2, located at the level of door 2 on the right-hand side, was not very distorted. Baskets and racks were compressed in the lower part of both galley carts.

The distortions observed in the metal vertical reinforcements of a toilet door showed evidence of significant compressive forces.

Fragments of the walls of the flight crew rest module were crumpled and those of the ceiling were deformed downwards. The floor was curved under the effect of a strong upward pressure from below. The connecting brackets between the floor and the walls were bent backwards.

1.12.4 Summary of visual examination

Observations of the tail fin and on the parts from the passenger (galley, toilet door, crew rest module) showed that the airplane had likely struck the surface of the water in level flight, with a high rate vertical acceleration.

1.13 Medical and Pathological Information

Sailors from the Frigate Ventôse recovered about thirty bodies. A visual examination of the bodies showed that they were clothed and relatively well preserved. All of them were handed over to the Brazilian Navy to be transferred to the Recife morgue.

At this stage of the investigation, the BEA has not yet had access to the autopsy data.

1.14 Fire

Based on the elements recovered up to now, no evidence of fire or explosion has been brought to light.

1.15 Survival Aspects

Given the current lack of information regarding the end of the flight, this chapter only deals with the launching and organization of the search and rescue operations.

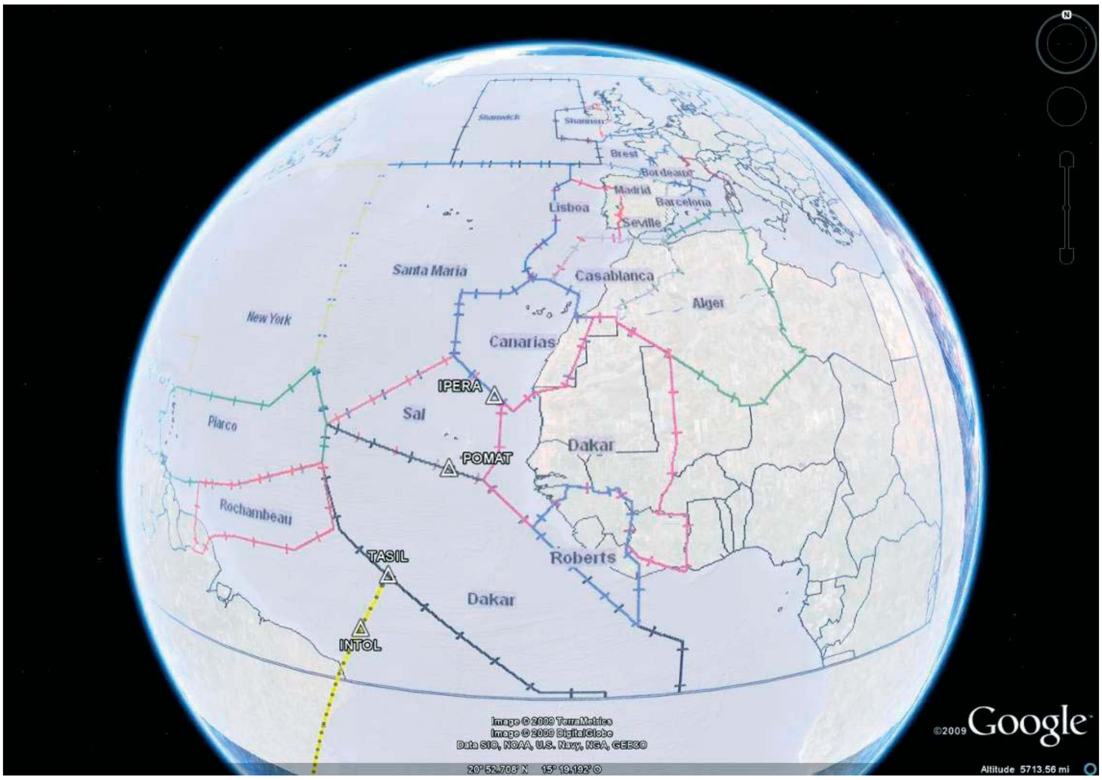
The chronology of events is based on the recordings from the ATC centres at Dakar and Brest and the Air France OCC. At this stage of the investigation, the BEA has not yet had access to the data from the Recife (ATLANTICO) and Sal (SAL OCEANIC) centres.

Synchronisation of the exchanges between the ATC centres is difficult and remains uncertain. In this chapter, the times have been rounded to the nearest minute, which is the scale of uncertainty.

The exchanges between the various control centres concerning the lack of contact with flight AF447 are detailed in Chapter 1.9 Communications.

The following table mentions, as an indication, the forecast times of entry of flight AF447 into the FIRs, estimated from the Initial Flight plan Processing System (IFPS) data, taking into account the last communication with the ATLANTICO centre, during which the crew announced that it was passing the INTOL point at 1 h 33.

ACC AND FIR CODE	TIME	REPORT POINT	COUNTRY
ATLANTICO (SBAO)	1 h 33	INTOL	BRAZIL
OCEANIC DAKAR (GOOO)	2 h 20	TASIL	SENEGAL
OCEANIC SAL (GVSC)	3 h 43	POMAT	CAPE VERDE
CANARIAS (GCCC)	4 h 37	IPERA	SPAIN
CASABLANCA (GMMM)	6 h 02	SAMAR	MOROCCO
LISBOA (LPCC)	6 h 47	BAROK	PORTUGAL
MADRID (LECM)	7 h 22	BABOV	SPAIN
BREST (LFRR)	8 h 01	DELOG	FRANCE
PARIS (LFFF)	8 h 35	NORMI	FRANCE



Representation of some of the FIRs crossed by the trajectory of flight AF447

The following timeline was made from the still fragmentary information collected at this stage, which will be supplemented during the investigation. Any interpretation that goes beyond the factual data mentioned could lead to erroneous analysis.

At 4 h 11, the DAKAR controller asked flight AF459 to contact flight AF447. The crew of flight AF459 sent a message to Air France at 4 h 18 so that the airline should try to contact flight AF447. At 4 h 24, Air France asked flight AF447 via ACARS to contact DAKAR OCEANIC.

At 5 h 50, after several unsuccessful attempts to obtain information on flight AF447, Air France contacted the SARSAT (Search and Rescue Satellite Aided Tracking) centre. The latter had not detected any beacon transmission. Acting upon the advice of SARSAT, Air France contacted the Cinq Mars La Pile Regional Control Centre.

At 6 h 00, the Cinq Mars La Pile Regional Control Centre called the BREST centre (CRNA west) and asked it to contact the centres involved with flight AF447. The BREST centre contacted the adjacent SHANWICK centre for it to contact the SANTA MARIA centre (Azores). The latter said that it did not have any information regarding the flight.

Between 6 h 04 and 6 h 12 the Air France OCC contacted successively the SANTA MARIA, SHANWICK and CANARIAS (Spain) centres to find out if they had had or could have contact with AF447, which could be in Moroccan airspace at that time. In parallel, the Air France OCC also informed the CNOA of the impossibility of getting in touch with AF447 and asked if there was any alternative means of detection. At the same time, the SHANWICK centre indicated to the BREST centre that the airplane would appear to be in Moroccan airspace.

At 6 h 05 the DAKAR controller confirmed to the ATLANTICO controller that the SAL controller still had no contact with flight AF447. At the same time, the CANARIAS centre sent a message to the DAKAR centre requesting information about flight AF447.

At 6 h 13, the BREST centre told the Cinq Mars La Pile Regional Control Centre that, according to an indirect source that had not been validated, flight AF447 had been in contact with Moroccan ATC.

At 6 h 17, the BREST centre contacted the adjacent MADRID centre to find out whether LISBOA ATC (Portugal) had information regarding the flight and if it could ask the crew to contact its airline.

A little later, the BREST centre sent a priority message to the LISBOA, MADRID and SANTA MARIA centres to request information regarding flight AF447 which was not in contact with its airline's operations control centre. It sent this message again at 6 h 24.

At 6 h 32, the BREST centre confirmed to the Cinq Mars La Pile Regional Control Centre that SANTA MARIA had no information about the flight.

At 6 h 35, the MADRID centre told the BREST centre that the flight was at that time in contact with CASABLANCA FIR and would enter the LISBOA FIR within a quarter of an hour. The BREST centre transmitted this information to the Air France Operations Control Centre and to the Cinq Mars La Pile Regional Control Centre.

At 6 h 44, after having contacted the CASABLANCA control centre, the Air France OCC called the BREST centre and informed it that CASABLANCA did not have contact (either by radio or radar) with the flight. The OCC specified that the CASABLANCA centre was in contact with AF459.

At 6 h 45, the BREST centre transmitted this information to the MADRID centre.

At 6 h 51, the MADRID centre confirmed that LISBOA had no radar contact and that CASABLANCA had neither radio nor radar contact with flight AF447. It specified that the flight should enter LISBOA airspace within ten minutes and then establish radar contact.

At 7 h 08, the MADRID centre informed the BREST centre that LISBOA had no radio or radar contact with AF447.

At 7 h 17, the BREST centre, which was then trying to locate flight AF447 in oceanic airspace, directly contacted the SANTA MARIA centre. The latter indicated that the DAKAR centre had had no contact with flight AF447 and that it was then supposed to be with the CASABLANCA centre. The BREST centre confirmed to SANTA MARIA that the CASABLANCA centre had no contact with flight AFR447. The SANTA MARIA centre then sought information from the CANARIAS centre.

At 7 h 29, the Air France OCC called the BREST centre to express its concerns over AF447. It stated that the airplane was not in contact either with Brazil or with Senegal and that the attempts at communication using the ACARS system, SATCOM and Stockholm radio were unsuccessful.

Note: Stockholm radio is a private operator based in Sweden that offers HF radio communications services. Air France is a client of Stockholm radio.

At 7 h 37, BREST called SANTA MARIA again, and the latter informed it that it had not had radar contact with AF447. SANTA MARIA added that DAKAR had coordinated AF447 with SAL but that the latter had had no radio or radar contact with the flight.

At 7 h 41, the DAKAR shift supervisor informed the Dakar Rescue Control Centre that flight AF447 should have passed the TASIL point at 2 h 20 but that it had not had any contact with the plane.

Shortly afterwards, the Air France OCC and then the BREST centre informed the BEA. The BREST centre planned to launch an alert phase at the forecast time of entry of the plane into the BREST UIR.

At 8 h 01, the BREST centre informed the Cinq Mars La Pile Regional Control Centre that it still had no news of flight AF447 and wondered whether it would be appropriate to launch an alert. The Cinq Mars La Pile Regional Control Centre said that it was not qualified to intervene since the event was outside its SAR responsibility zone.

At 8 h 07, the LISBOA and SANTA MARIA centres replied to the BREST centre saying that they had no news of flight AF447.

At 8 h 15, the MADRID centre launched an INCERFA-ALERFA phase.

At 8 h 34, the BREST centre launched a DETRESFA phase and called the Cinq Mars La Pile Regional Control Centre.

At 8 h 37, the air traffic control services at Paris Charles de Gaulle airport asked their counterparts in Dakar for information on flight AF447.

At 9 h 09, the BREST centre sent a DETRESFA message to some centres along the route of flight AF447. The message indicated an estimated position between the ORARO and TASIL report points.

At 9 h 31, the SAL centre, which was not the recipient of the message from BREST, sent an ALERFA-INCERFA message to the DAKAR centre.

At 9 h 40, the Dakar rescue control centre informed the Dassault Atlantique detachment that the control centre had not had contact with a plane that should have crossed the DAKAR OCEANIC FIR. The head of the Naval Aviation detachment contacted the military authorities in France: the Brest Maritime Operations Centre, the National Air Operations Centre (CNOA) and the Gris Nez centre[15].

At 9 h 50, the head of the Naval Aviation detachment launched a heightened alert (one hour notice and additional fuelling carried out).

At 10 h 45, the Dakar rescue control centre gave the takeoff order to the Dassault Atlantique 2 to position itself at Cape Verde. This was a pre-positioning choice given the uncertainty about the location of the accident.

[15]Gris-Nez is the French correspondent of the foreign search and rescue centres. It centralizes and deals with alerts transmitted by French ships sailing on all of the world’s seas. It cooperates with maritime rescue coordination centres (MRCC), which are counterparts within the framework of the world distress and safety-at-sea system.

The CNOA then indicated a probable search area to the head of the detachment, between Cape Verde and Brazil, indicated by Air France and confirmed by the BEA at 11 h 07.

At 12 h 14, the Dassault Atlantique 2 took off bound for Cape Verde[16].

Around 13 h 00, the crew of the Dassault Atlantique 2, en route to position at Cape Verde, received the instruction to proceed towards TASIL descending UN 873 airway.

The Dassault Atlantique 2 arrived over the search area at 15 h 28. It landed back in Dakar at 22 h 20 without having detected any debris.

The low altitude searches were coordinated by the Recife MRCC, the airplane having disappeared in its zone of SAR responsibility.

[16]Take-off was delayed for approximately thirty minutes due to technical problems.

1.16 Tests and Research

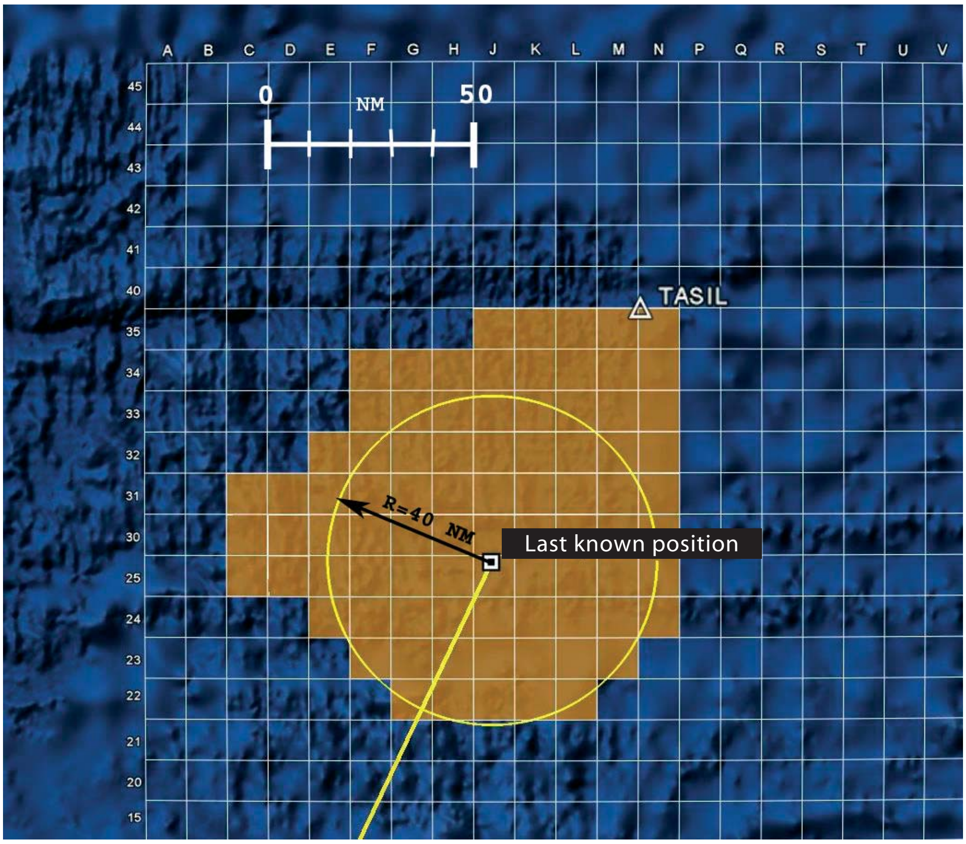
1.16.1 Sea Searches

1.16.1.1 Context of the searches

The estimated area of the accident is over the Atlantic Dorsal Chain. The search is proceeding there in an unfavourable environment due to the depth and to the topography of the seabed. This seabed is little known and presents, over short distances, depths going from 900 metres to approximately 4,600 metres. The distance from dry land implies a lack of radar coverage and radio communication difficulties.

The search area was initially defined based on the airplane's route and the last position contained in the ACARS messages. This makes an area with a radius of 40 NM, extending over more than 17,000 km^2 and located more than 500 NM from the coasts.

The searches on the surface made it possible to locate bodies and airplane parts from 6 June onwards. The position of the floating elements allowed a search zone to be defined based on the work on the currents and the winds. The following figure shows the underwater search area.



Size of the search area

1.16.1.2 Principle of the underwater searches

As the aircraft's recorders were each equipped with an underwater locator beacon, it was best to prioritise an acoustic search initially, nevertheless taking into account the limited range of the beacons, which is about two kilometres at most. The propagation of acoustic waves in a liquid medium, which depends on many interdependent parameters such as the salinity and the temperature of the water, must also be taken into account. When an acoustic wave is propagated in the sea, it is subjected to refractions and this generates multiple trajectories. The acoustic waves may also be deflected in such a way that there is a «shadow» region which is never reached by these waves.

Acoustic searches using beacons which transmit at 37.5 KHz (± 1 KHz) are in general more effective than searches using sonar, magnetometers and video cameras. Nevertheless, the duration of the beacon transmission is limited, being certified for a minimum transmission duration of thirty days from immersion.

Taking into account the range of the beacons, the hydrophones must be brought closer to the source of transmission, by towing specialized equipment near the seabed.

The underwater search devices that are used after localisation of the wreckage must also take into account the depth and uncertainty of the area. In the case of the accident to flight AF447, provision has been made for specialized devices able to descend to a depth of six thousand metres.

1.16.1.3 Resources deployed by France

By the Ministry of Defence

The French Navy deployed the frigate Ventôse and the Mistral BPC (projection and command ship), which have been taking part in the search and recovery operations for the bodies and floating debris. They have been assisted by their on-board helicopters and Naval Aviation and Air Force planes.

The Emeraude (hunter killer nuclear submarine) was sent to the area to complete the acoustic search system.



Ventôse frigate *Submarine Emeraude* *Mistral*

By the BEA

In relation to towed acoustic devices, the BEA approached the US Navy. The latter has two towed pinger locator (TPL) hydrophones and uses them regularly to search for civil or military aircraft crashed at sea.

The US Navy TPLs can operate at up to a depth of six thousand metres. They operate on a waveband between 5 and 60 KHz which includes the frequency transmitted by the underwater locator beacons. The average detection range of the TPLs is estimated at two kilometres at least.

To optimize the use of this equipment, the BEA chartered two available ships from the Dutch subsidiary of Louis-Dreyfus Armateurs. These two tugs were the "Fairmount Expedition" and the "Fairmount Glacier".

The BEA also chartered the oceanographic ship «Pourquoi Pas ?» from IFREMER together with its specialized exploration and intervention resources, the "Nautile" submarine and the "Victor 6000" ROV, which are able to operate at a depth of up to six thousand metres. These vehicles can also map the site of the accident.

The "Pourquoi Pas?" has acoustic detection equipment on board:

- ❒ an acoustic Repeater,
- ❒ a SMF (multi-beam sonar) modified to operate in passive mode,
- ❒ "ROV homer" directional hydrophones, which can be adapted to the underwater intervention resources.

1.16.1.4 Organisation of the underwater searches

Before the tugs and the submarine arrived at the estimated site of the accident, a grid network was made for the search area at the CECLANT centre in Brest by the French Navy and the BEA. The area was thus divided into blocks with sides measuring ten arc-minute lengths (that is to say squares with sides measuring approximately 10 NM at these latitudes, see figure in 1.16.1.1). In most of these blocks, depths can exceed 3,500 m. The working areas were distributed between the surface ships and the underwater resources so that the search was carried out rapidly under good safety conditions.

The tactical coordination of the searches takes place on board of the "Pourquoi Pas?". It is being conducted by the BEA together with the CEPHISMER personnel (French Navy).

The SHOM detachment on board the "Pourquoi pas?" is working to improve the knowledge of the topography of the area. The deep sea multi-beam probe can be used to collect depth data. Current measurement data and data related to the measurement of the speed of sound in the water are also being processed.

In order to use the towed pinger locators, they are towed at approximately three knots as close as possible to the seabed. In order to systematically cover the area, the tugs use lines with a spacing of 2.5 km. This takes into account the scan swath of the TPL which is approximately 2 NM.

1.16.2 ACARS messages

1.16.2.1 ATC messages

No ATC messages were received or transmitted by F-GZCP. Only three attempts were made to connect with the Dakar centre ADS-C system and were recorded on 1st June at 1 h 33, 1 h 35 and 2 h 01. The three requests were refused with a FAK4 code, meaning that the control system had detected the absence of a flight plan for this aircraft or that there was a mismatch between the flight plan filed for this registration number, the flight number and the reported position.

1.16.2.2 Operational messages

The first position message (AOC type message) was transmitted on 31 May at 22 h 39. On 1st June at 2 h 10 min 34, the last position received was latitude +2.98° (North) and longitude -030.59° (West). The position transmitted was the aircraft's FM position which, in normal conditions, is close to the GPS position.

Other operational messages were sent to the aircraft, including aircraft loading data (load sheet), takeoff charts and meteorological information.

1.16.2.3 Maintenance messages

Twenty-six maintenance messages relative to flight AF447 were received. Twenty-four of them were received on 1st June between 2 h 10 and 2 h 15.

The first two messages were received the day before at 22 h 45. These were a class 2 fault message and a related MAINTENANCE STATUS TOILET cockpit effect message. The fault message, "LAV CONFIGURATION" (ATA 383100, source VSC*, HARD) represented a toilet configuration difference between the airplane and that included in one of the associated systems.

1.16.2.4 Analysis of the messages received on 1st June from 2 h 10 onwards

The messages received on 1st June after 2 h 10 all transited via the same satellite (Atlantic Ocean West, operated by the Inmarsat Company) and SITA's ACARS network. The twenty-four raw maintenance messages are listed in the table below:

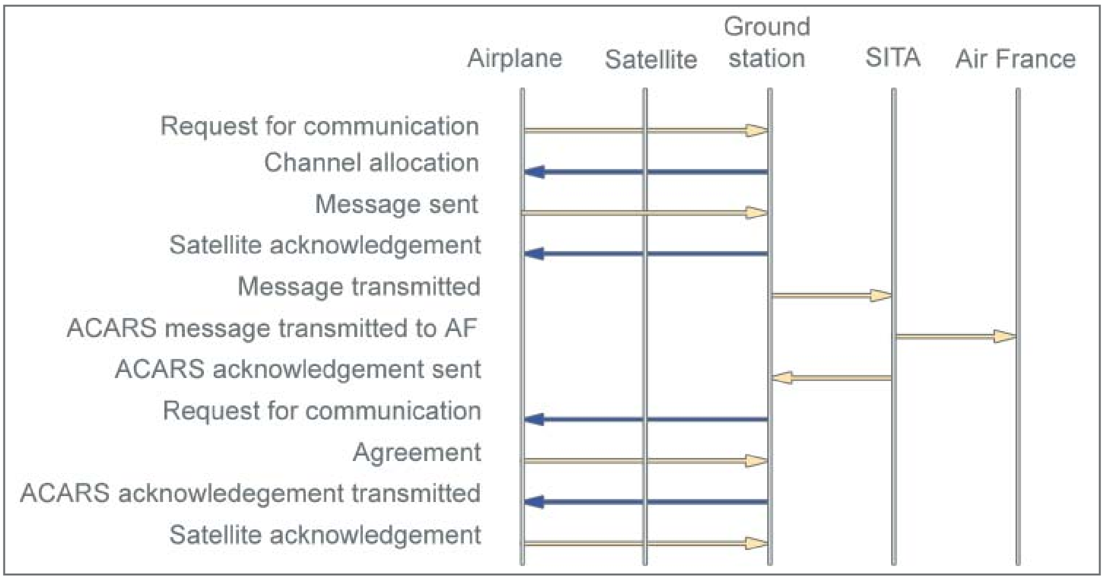
Time of reception[17]	Message
02:10:10	- .1/WRN/WN0906010210 221002006AUTO FLT AP OFF
02:10:16	- .1/WRN/WN0906010210 226201006AUTO FLT REAC W/S DET FAULT
02:10:23	- .1/WRN/WN0906010210 279100506F/CTL ALTN LAW
02:10:29	- .1/WRN/WN0906010210 228300206FLAG ON CAPT PFD SPD LIMIT
02:10:41	- .1/WRN/WN0906010210 228301206FLAG ON F/O PFD SPD LIMIT
02:10:47	- .1/WRN/WN0906010210 223002506AUTO FLT A/THR OFF
02:10:54	- .1/WRN/WN0906010210 344300506NAV TCAS FAULT
02:11:00	- .1/WRN/WN0906010210 228300106FLAG ON CAPT PFD FD
02:11:15	- .1/WRN/WN0906010210 228301106FLAG ON F/O PFD FD
02:11:21	- .1/WRN/WN0906010210 272302006F/CTL RUD TRV LIM FAULT
02:11:27	- .1/WRN/WN0906010210 279045506MAINTENANCE STATUS EFCS 2
02:11:42	- .1/WRN/WN0906010210 279045006MAINTENANCE STATUS EFCS 1
02:11:49	- .1/FLR/FR0906010210 34111506EFCS2 1,EFCS1,AFS,,,,,,PROBE-PITOT 1X2 / 2X3 / 1X3 (9DA),HARD
02:11:55	- .1/FLR/FR0906010210 27933406EFCS1 X2,EFCS2X,,,,,,,FCPC2 (2CE2) / WRG:ADIRU1 BUS ADR1-2 TO FCPC2,HARD
02:12:10	- .1/WRN/WN0906010211 341200106FLAG ON CAPT PFD FPV
02:12:16	- .1/WRN/WN0906010211 341201106FLAG ON F/O PFD FPV
02:12:51	- .1/WRN/WN0906010212 341040006NAV ADR DISAGREE
02:13:08	- .1/FLR/FR0906010211 34220006ISIS 1,,,,,,,,ISIS(22FN-10FC) SPEED OR MACH FUNCTION,HARD
02:13:14	- .1/FLR/FR0906010211 34123406IR2 1,EFCS1X,IR1,IR3,,,,ADIRU2 (1FP2),HARD
02:13:45	- .1/WRN/WN0906010213 279002506F/CTL PRIM 1 FAULT
02:13:51	- .1/WRN/WN0906010213 279004006F/CTL SEC 1 FAULT
02:14:14	- .1/WRN/WN0906010214 341036006MAINTENANCE STATUS ADR 2
02:14:20	- .1/FLR/FR0906010213 22833406AFS 1,,,,,,,,FMGEC1(1CA1),INTERMITTENT
02:14:26	- .1/WRN/WN0906010214 213100206ADVISORY CABIN VERTICAL SPEED

[17] The reception time given is that of the service provider's server processor

Note: A position report message (AOC type) was received at 2 h 10 min 34 s, between two maintenance messages. This can be explained by the fact that AOC messages take priority over maintenance messages.

The messages were at least five or six seconds apart, which can be explained by the limited rate of communication by satellite. There are two possible reasons for the longer gaps: either the aircraft did not have any messages to transmit, or it no longer had the means for doing so (loss of satellite communication performance, for example).

When a message is sent by the aircraft, the sequence is as follows:



The company that operates the satellite used by AF447 has provided the traces of the messages transmitted to the aircraft and seen by the satellite. The information analysed makes it possible to say that:

- the last message was transmitted to the aircraft at 2 h 14 min 28 s and was effectively received,
- the twenty-five messages transmitted by the aircraft were correctly received by the ground station,
- the gap observed between the message sent at 2 h 13 min 14 s and the one sent at 2 h 13 min 45 s is due, at least in part, to a temporary interruption in the communication link between the aircraft and the satellite,
- there were no satellite telephone communications during the flight.

Interpretation of the messages

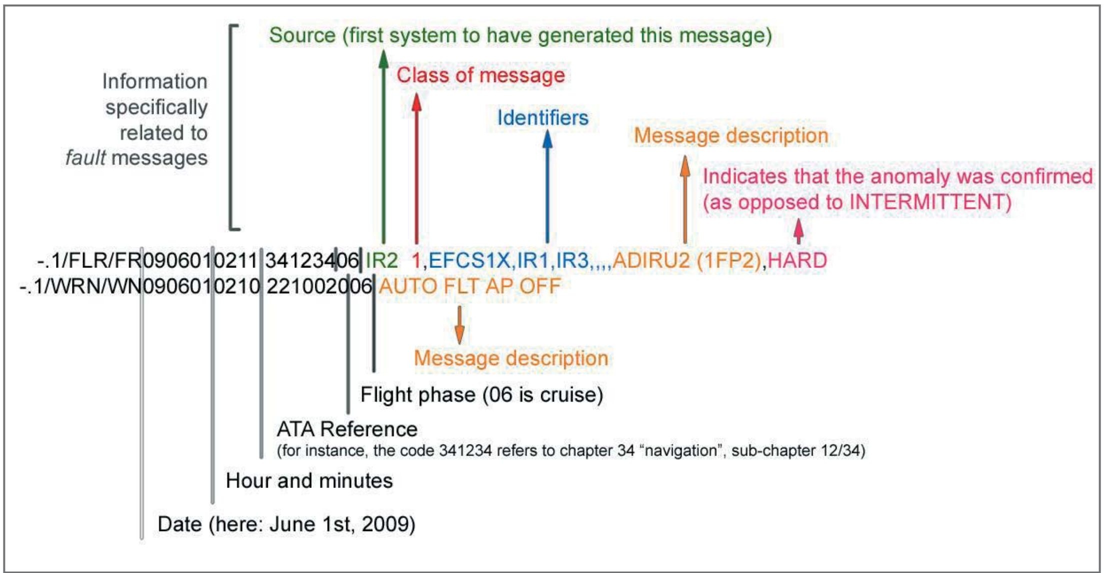
Interpretation of the maintenance-related messages is made delicate by the following factors:

- this type of message is only transmitted once, at the first occurrence. It can only indicate that a fault has appeared. If the fault has disappeared, no message is transmitted to indicate this,
- some messages concerning the aircraft's configuration such as stall or overspeed warnings are not recorded,

- message-timing by the CMC is accurate to within one minute,
- the order in which these messages are transmitted does not necessarily correspond to the associated sequence of events,
- the limited rate of communication by satellite does not make it possible to determine directly the time of message reception precisely to the nearest second,
- in the CFR, a class 1 fault message is not necessarily accompanied by a cockpit ef-fect, and it is possible that a cockpit effect message is not the consequence of a fault message.

fault : - .1/**FLR**/FR0906010211 34123406IR2 1,EFCS1X,IR1,IR3,,,,ADIRU2 (1FP2),HARD
cockpit effect : - .1/**WRN**/WN0906010210 221002006AUTO FLT AP OFF

The information contained in a message differs depending on the type of message. Some of this information may be common:



Note: the fault messages generated by the EFCS are always of the HARD type.

Analysis of the cockpit effect messages

Note: when cockpit effect type messages are associated with procedures, the latter are referenced in appendix 5.

The cockpit effect messages are described in the order in which they appear on the CFR. The theoretical symptoms in the cockpit are given for each one taken separately: the ECAM message, the visual and aural warnings, the SD page called up and the local alarms that correspond to it.

AUTO FLT AP OFF (2 h 10)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
AUTO FLT AP OFF	Cavalry charge	Master warning	-	-	no

Meaning: This message indicates an autopilot disconnection other than by pressing the push-button provided for that purpose on the control sticks (instinctive disconnect).

AUTO FLT REAC W/S DET FAULT (2 h 10)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
AUTO FLT REAC W/S DET FAULT	Single chime	Master caution	-	-	no

Meaning: This message indicates unavailability of the reaction to wind shear detection function.

F/CTL ALTN LAW (2 h 10)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
F/CTL ALTN LAW (PROT LOST)	Single chime	Master caution	-	-	no

The green symbols showing the attitude protections on the PFD are replaced by amber crosses.

Meaning: This message indicates switching to alternate flight control law.

FLAG ON CAPT PFD SPD LIM and FLAG ON F/O PFD SPD LIM (2 h 10)

Symptoms: Disappearance of the display of the characteristic speeds (in particular VLS and green dot) on the Captain and First Officer PFDs, with display of the SPD LIM flag at the bottom of the speed scales.

Meaning: This message indicates the unavailability of the FMGEC's characteristic speed calculation function.

AUTO FLT A/THR OFF (2 h 10)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
AUTO FLT A/THR OFF	Single chime	Master caution	-	-	no

Meaning: This message indicates disconnection of the auto-thrust other than by pressing the button provided for that purpose on the throttle control levers (instinctive disconnect) or that the throttle control levers were moved to the idle notch.

NAV TCAS FAULT (2 h 10)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
NAV TCAS FAULT	-	-	-	Flag on PFD and ND	no

Meaning: This message indicates that the TCAS is inoperative. At this stage of the investigation, this message has not been fully explained.

FLAG ON CAPT PFD FD and FLAG ON F/O PFD FD (2 h 10)

Symptoms: Disappearance of the Flight Director on the PFDs, Captain and First Officer sides, and display of the red FD flag.

Meaning: This message indicates the Flight Director function is selected and unavailable.

F/CTL RUD TRV LIM FAULT (2 h 10)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
F/CTL RUD TRV LIM FAULT	Single chime	Master caution	F/CTL	-	no

Meaning: This message indicates the unavailability of the rudder deflection limitation calculation function. The limitation value remains frozen at the current value at the time of the failure (until the slats extension command is given).

MAINTENANCE STATUS EFCS2 and MAINTENANCE STATUS EFCS1 (2 h 10)

These ECAM messages are not brought to the attention of the crew in flight.

FLAG ON CAPT PFD FPV and FLAG ON F/O PFD FPV (2 h 11)

Symptoms: Disappearance of the FPV (bird) on the PFDs, Captain and First Officer sides, and display of the red FPV flag.

Meaning: This message indicates that the FPV function is selected and unavailable.

NAV ADR DISAGREE (2 h 12)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
NAV ADR DISAGREE	Single chime	Master caution	-	-	no

Meaning: This message indicates that the EFCSs have rejected an ADR, and then identified an inconsistency between the two remaining ADRs on one of the monitored parameters.

F/CTL PRIM 1 FAULT (2 h 13)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
F/CTL PRIM 1 FAULT	Single chime	Master caution	F/CTL	"Fault" light on corresponding button	no

Meaning: This message indicates that FCPC1 (PRIM 1) has stopped functioning. This shutdown could be the result of a command or of a failure.

F/CTL SEC 1 FAULT (2 h 13)

ECAM Alarm	Aural warning	Visual warning	SD page	Local alarm	Inhibited in phase 6
F/CTL SEC 1 FAULT	Single chime	Master caution	F/CTL	"Fault" light on corresponding button	no

Meaning: This message indicates that FCSC1 (SEC 1) has stopped functioning. This shutdown could be the result of a command or of a failure.

MAINTENANCE STATUS ADR2 (2 h 14)

This ECAM message is not brought to the attention of the crew in flight.

ADVISORY CABIN VERTICAL SPEED (2 h 14)

Symptoms: Flashing of the cabin vertical speed indicator on the SD's PRESS page.

Meaning: This message indicates a cabin altitude variation greater, as an absolute value, than 1,800 ft/min for five seconds.

Analysis of the fault messages

Five fault messages were received by ACARS. They are described in the order in which they appear in the CFR.

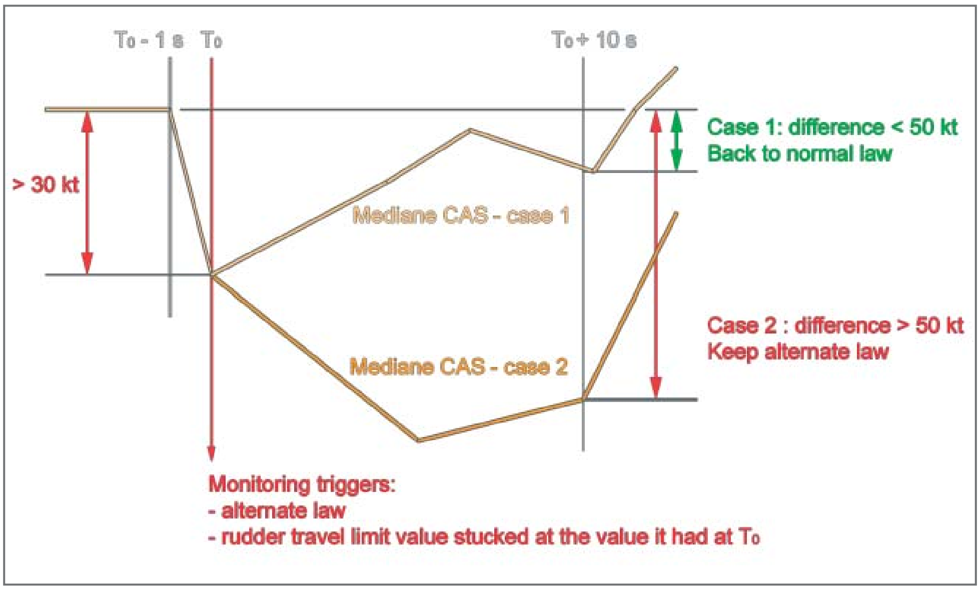
PROBE PITOT 1+2 / 2+3 / 1+3 (9DA) (2 h 10)

ATA: 341115
Source: EFCS2
Identifiers: EFCS1, AFS
Class 1, HARD

This message, transmitted by the FCDC2 (EFCS2), means that the FCPCs (or PRIMs) triggered one of the speed monitoring processes: they have detected a decrease of more than 30 kt in one second of the "polled" speed value. The three ADRs were considered valid by the EFCS2 at the time the monitoring was triggered, because the prior rejection of an ADR would have generated a class 2 fault message and there would therefore have been an asterisk in front of the source. In this case, the "polled" value is the median value.

At the time this monitoring is triggered, the FCPCs open a window during which they operate with alternate 2 law (see following graphic). The rudder deflection limitation function is also frozen, but the associated alarm is inhibited. At the end of the window, if the difference between the values polled at each end of that window is less than 50 kt, the FCPCs return to normal law. Otherwise, they continue in alternate 2 law, the rudder deflection limitation function remains unavailable and the corresponding alarm is generated.

Note: the alternate 2 control law is a load factor law for pitch and a direct law for roll. Only the load factor protection remains available. In certain cases, the high and low speed stabilities may also be lost.



The presence of the F/CTL RUD TRV LIM FAULT message indicates that EFCS monitoring had been activated and that the alternate law had been maintained. The rudder deflection limitation value then remained the same as that before monitoring was triggered.

The identifiers are:

- EFCS1: the FCDC1 is a clone of FCDC2 and it is therefore probable that the message transmitted by EFCS1 was the same. However, it is not possible to state this categorically at this stage of the investigation because around twenty messages can be generated by the EFCSs with an ATA code starting with 341.
- AFS: it does not perform this specific monitoring but can generate a message with an ATA code starting with 341 further to the triggering of another monitoring process that does not explicitly point to the speeds, unlike FCPC monitoring. The fact that the AFS is an identifier nevertheless implies that the monitoring was triggered in the same minute as that of EFCS2 monitoring.

This message, in itself, and the identifiers that are associated with it therefore indicate the triggering of distinct monitoring processes, one of which is explicitly linked to the speeds delivered by the ADRs. The combined triggering of these monitoring processes has the following effects:

- at the level of the EFCSs:
  - switch to alternate 2 control law,
  - unavailability of the rudder deflection limitation function which occurs, when applicable, ten seconds later.
- at the level of the AFS:
  - unavailability of the autopilot,
  - unavailability of the auto-thrust,
  - unavailability of the flight director function,
  - unavailability of the characteristic speeds calculation function,
  - unavailability of the reaction to wind shear detection function.

FCPC2(2CE2)/WRG:ADIRU1 BUS ADR1-2 TO FCPC2 (2 h 10)

ATA: 279334
Source: *EFCS1
Identifiers: *EFCS2
Class 2, HARD

This message indicates that FCPC 2 no longer considers as valid the information that is delivered to it by ADR 1 (via bus 2). The ATA code beginning with 27 indicates that the fault was not detected by any other FCPC during the three seconds that followed (otherwise this message would have been classified ATA 34). This message has not been fully explained at this stage of the investigation.

ISIS (22FN-10FC) SPEED OR MACH FUNCTION (2 h 11)

ATA: 342200
Source: ISIS
Identifiers: -
Class 1, HARD

This message, transmitted by the ISIS, may be the consequence of:

- an internal failure at the level of the CAS or Mach elaboration function,
- CAS or Mach values that are outside certain limits.

If the CAS is outside those limits, the SPD flag is displayed on the ISIS speed scale. If the Mach exceeds the upper limit, the M flag is displayed instead of the Mach. If it is lower than the lower limit, the Mach value is no longer displayed but this flag does not appear. The display of these flags is not captured by the CMC that the aircraft was equipped with.

ADIRU2 (1FP2) (2 h 11)

ATA: 341234
Source: IR2
Identifiers: *EFCS1, IR1, IR3
Class 1, HARD

This message has not been fully explained at this stage of the investigation. It was generated by IR 2, but it is possible that the correlation window had been opened by EFCS 1 via a class 2 message.

FMGEC1 (1CA1) (2 h 13)

ATA: 228334
Source: AFS
Identifiers: -
Class 1, INTERMITTENT

This message has not been fully explained at this stage of the investigation. The fact that it was "INTERMITTENT" means that the fault was detected for less than 2.5 seconds.

1.16.2.5 Partial conclusion

At this stage of the investigation, the messages analysed allow us to conclude that various monitoring processes were triggered. At least one of them corresponds to an inconsistency in the speed measurements. Several of the cockpit effects messages recorded could correspond to the consequences of these monitoring processes:

- AUTO FLT AP OFF,
- AUTO FLT A/THR OFF,
- AUTO FLT REAC W/S DET FAULT
- F/CTL RUD TRV LIM FAULT,
- F/CTL ALTN LAW,
- FLAG ON CAPT (F/O) PFD SPD LIM,
- FLAG ON CAPT (F/O) PFD FD.

Note: the CFR was designed to facilitate maintenance operations; it is therefore not intended to be used for investigation purposes.

1.17 Information on Organisations and Management

1.17.1 Preparation of flights within Air France

Two units take part in the preparation of flights:

- the Central Flight Study service, responsible for drawing up the flight dossier,
- the departure station, responsible for providing the crew with the flight dossier, which may be supplemented with local information («departing flights» function).

An operational flight dossier is made up of three parts:

- part A containing, in particular, the operational flight plan or plans and the ATC flight plan, the aeronautical information (NOTAM),
- part B containing the regulatory meteorological charts (TEMSI, wind and temperature charts) as well as supplementary CAT charts at different flight levels,
- part C containing a chain of meteorological information consisting of TAF and METAR as well as SIGMET.

1.17.1.1 Central flight study service

The central flight study service is organised into three entities located within the Operations Control Centre, located in the Air France headquarters at Paris Charles de Gaulle airport, consisting of:

- technicians responsible for preparing part A of the flight dossiers,
- technicians responsible for managing slots and monitoring the ATC flight plans,
- dispatchers monitoring the flights.

Preparation of flight dossiers

Part A of the long-haul flight dossier is prepared with the help of computer programmes (MISTRAL, SAILOR and OCTAVE). The data used is that available at the time of preparation of the dossier, between seven and three hours before the programmed departure.

The following data items are taken into account for drawing up part A:

- the estimated loads (freight and passengers),
- the weight and consumption data specific to the aircraft,
- the NOTAM's (for en route restrictions and dangerous areas),
- the meteorological parameters used in the operational flight plan calculation tool (OCTAVE), updated at 4 h 00 and 16 h 00,
- the information supplied by the originating station for calculating the limitations on take-off (runway in service, temperature, QNH, state of the runway) along with the NOTAM's of the departure airport,
- the MEL / CDL items declared by the maintenance services and relevant for this part,
- the TAF and NOTAM taken into account for the automatic determining of the accessibility of the destination, alternate and ETOPS support aerodromes,
- the one or more TEMSI used to take into account any significant meteorological phenomena.

The sending of the ATC flight plan ends this preparation. This triggers the automatic generation of the information in part B of the dossier. The flight dossier, made up of parts A and B can then be printed by the station. In the case of certain stations, depending on national regulations, when the airline sends the flight plan it is not automatically submitted, as this must be done locally. This is the case at Rio de Janeiro. For this station, the central flight study service sends the ATC flight plan to the Brazilian Air Traffic Control Service (at the address SBGLYOYX) with all of the addresses of the FIR control centres to be crossed in box 18 of the ATC flight plan. The latter service then submits the flight plan to all of the FIR control centres involved.

ATC cell

The ATC cell monitors the resetting of times for the entire fleet as well as the management of take-off slots for the Eurocontrol zone.

Dispatch

The dispatchers carry out the function of monitoring flights from three hours before departure until the arrival of the aircraft. They make the regulatory contact before the aircraft's entry into an ETOPS zone. They reply to the requests made by crews on the ground or in flight. They monitor changes in meteorology and NOTAM's.

1.17.1.2 Flight Departure

The agent who carries out the flight departure function at the station physically puts together the flight dossier that he hands over to the crew. He prints parts A and B about three hours before the flight's departure. He prints part C shortly before the crew's arrival. He puts together the sets of drawings for the flight dossier and traces the ETOPS strip charts for the flights concerned.

Once the crew has studied the flight dossier, the captain signs the "PPV copy" form specifying the quantity of fuel as well as the alternate airfield that he chooses at take-off. This copy is archived at the departure station. For ETOPS flights, the meteorological forecasts used for the accessibility of the support airfields chosen are copied onto this same document.

1.17.1.3 Preparation of flight AF447 on 31 May 2009

Preparation of the flight by the central flight study service

The flight was prepared between 15 h 28 and 18 h 59. Paris Orly was given as the alternate airport at destination. Given the estimated load of 37.8 t, the dossier included a main flight plan at a standard Mach of M 0.82 with an ETF at Bordeaux Mérignac with alternate at Toulouse Blagnac as well as two additional direct flight plans, one at Mach 0.82 and the other at a "slower Mach", i.e. M 0.81. A summary table of the loads offered enabled the crew to make the choice of the definitive flight plan from among these three options.

The preparation agent sent the ATC flight plan at 18 h 57. He stated that he did not notice anything specific during the preparation of this flight. There was no intervention by the ATC cell, as the flight was planned at the time programmed.

Preparation of the flight at Rio

The flight departure agent started printing the dossier at 19 h 02.

The Brazilian air traffic control service submitted the ATC flight plan to the air traffic control bodies of the regions overflown at 19 h 12. Note, however, that the address of the DAKAR control centre (GOOO) was not part of the ATC flight plan submitted by this service. Conversely, this address appeared in the flight plan sent by Air France (see appendix 6).

F-GZCP, coming in from Paris Charles de Gaulle, arrived at the gate at 20 h 05, for an arrival scheduled at 20 h 00. The minimum turnaround time for this stopover is 115 minutes.

The flight crew of flight AF447 arrived at the flight preparation room at the station at around 20 h 00.

The flight departure agent handed over the dossier to the crew. He stated that the crew did not seem worried and that, in his opinion, no particular event hindered the preparation of the flight. The dispatcher did not remember a call coming from this crew during preparation of the flight. There was no modification of the dossier.

The PPV copy signed by the captain confirmed planned trip fuel of 63.9 t with refuelling at the ramp of 70.9 tonnes and planned taxiing of 0.5 t (giving 70.4 t on take-off). The study of the routes in the dossier and the associated fuel loads is in appendix 7. The fuel load policy is given in appendix 8.

The crew informed the Rio station of its choice of a direct flight at M 0.82.

The start-up clearance was obtained at 22 h 10.

Meteorological data in the flight dossier

The part B meteorological charts were printed in black and white with the route traced by computer. The following charts were handed over to the crew:

- the TEMSI chart valid on 1st June at 00 h 00 between FL 250 and FL 630,
- the wind and temperature charts valid on 1st June at 00 h 00 at FL100, FL180, FL300, FL340 and FL390,
- the CAT charts valid on 1st June at 00 h 00 at FL340 and FL390 (no clear air turbulence was forecast).

Part C of the flight dossier contained the TAF and METAR of the departure, destination and alternate airports and relevant airports on the route, including the ETOPS support airports along with the SIGMET.

A dossier thus constituted meets the regulatory requirements.

The criteria for selecting a SIGMET in a flight dossier via EOLE are:

1. the FIR involved with regard to the planned route,

2. the validity at the time of printing of the set of documents.

Note: ICAO Annex 3 does not impose any requirements related to the selection of the SIGMETs.

According to testimony, the request for the printing of part C of the flight dossier was made after the printing of parts A and B of the dossier and shortly before the arrival of the crew, i.e. between 19 h 00 and 20 h 00. The time of this transaction was not recorded. In this interval, the SIGMETs that satisfied the selection criteria were:

- SIGMET 5 SBRE (RECIFE) of 31 May from 18 h 00 to 22 h 00
- SIGMET 7 SBAO (ATLANTICO) of 31 May from 18 h 00 to 22 h 00
- SIGMET 7 GOOO (Oceanic DAKAR) of 31 May from 16 h 35 to 20 h 35. The route of flight AF447 did not enter into the area of this SIGMET.

Note: the EU-OPS regulations specify that the operator must ensure that the information on the flight is retained on the ground until it has been copied and archived. By "information on the flight" it means:

- a copy of the operational flight plan,
- a copy of the relevant parts of the aircraft's equipment report,
- the NOTAMS concerning the route if they are specifically printed out by the operator,
- the documentation about the weight and balance,
- the notifications concerning the special loads.

The documents about meteorological information supplied to crews are not subject to this requirement.

The crew also had the option of using a computer application (EOLE) to consult a colour screen showing other meteorological charts (particularly the tropopause and icing chart) and satellite photos and printing them in black and white.

Note: on the crew's OCTAVE flight plan there was additional turbulence information (SHEAR RATE) calculated according to the estimated wind gradient, between 0/1/2, weak and 7/8/9, strong. Between the NTL and CVS reporting points the highest value was 2, around point INTOL. This value did not take into account turbulence of convective origin.

1.17.1.4 Flight follow-up

The following operational information was exchanged via ACARS:

- at 22 h 51 the crew asked for and received the METAR of the Brazilian airfields of Belo Horizonte, Salvador de Bahia and Recife,
- at 0 h 31 dispatch sent the following message:
  "BONJOUR AF447
  METEO EN ROUTE SAILOR :
  - o PHOTO SAT DE 0000Z : CONVECTION ZCIT SALPU/TASIL
  - o PREVI CAT : NIL
  - SLTS DISPATCH",
- at 0 h 33 the crew asked for and received the METAR and TAF of Paris Charles de Gaulle, San Salvador and Sal Amilcar airports,
- at 0 h 57 the crew inquired about the use of the second ETOPS support aerodrome and dispatch replied at 1 h 02
- at 1 h 13 the crew asked for and received the Dakar, Nouakchott and Natal METAR and TAF,
- the regulatory bilateral contact before entering an ETOPS zone (SALPU, estimated at 1 h 48 by the crew) took place between 1 h 17 and 1 h 19.

Note: the crew could take the option of requesting SIGMET by ACARS. This functionality was not used by the crew.

1.17.2 Work cycles and flight crew rest

1.17.2.1 Regulatory references

The limitations on flying time and requirements in terms of flight crew rest were harmonised at a European level by EU-OPS (Sub-part Q of Appendix III). As of 1st June 2009, the applicable version of EU-OPS is that of Commission Regulation 859/2008, dated 20 August 2008 modifying Regulation 3922/91.

At a national level, these provisions were completed by the Order of 25 March 2008, made in application of the EU-OPS, modified by the Orders of 13 June 2008 and 9 July 2008.

The objective of Sub-part Q, to guarantee that crews have sufficient rest to ensure the safety of flights, is presented in EU-OPS 1.1090. To satisfy this

objective, Sub-part Q introduces two major principles: flight duty time and the minimum rest period before flight duty (EU-OPS 1.1110). Therefore, EU-OPS only deals with rest periods preceding a series of flights; the rest periods after a series of flights are considered to be part of the social domain and, due to this, are taken into account in France by the Civil Aviation Code, in particular its Articles D422-1 to 13.

1.17.2.2 Parts of the regulations applicable to flight AF447

For a flight without a stopover the daily flying duty time[18], including the flight preparation tasks, is limited to 13 hours. In the case of a night flight (in the assumed low phase of the circadian rhythm) this time is reduced by two hours as a maximum depending on the period of the night in question. This time may be extended up to 18 hours by reinforcing the crew (three flight crew members for an aircraft certified with two pilots) when the flight crew have a rest facility separated from the cockpit and isolated from the passengers, that is a couchette (which was the case on board F-GZCP).

[18] This time is counted from the moment when the crew member must present himself, at the operator's request, for a flight or series of flights and ends at the end of the last flight during which the crew member is on duty (see EU-OPS 1.1095 § 1.6).

Each member of the flight crew must be able to rest for at least one hour thirty minutes continuously during flying duty time.

1.17.2.3 Air France Procedures

Composition of the flight crew

The airline agreements signed with the flight personnel's trade union organisations organise the flight time limitations and rest periods within Air France according to requirements that are more restrictive than the regulations in force.

Within this framework, the maximum flying duty time is set at ten hours. This flying duty time can be extended to sixteen and a half hours by reinforcing the crew. The flight time can be extended to thirteen and a half hours.

Since the programmed flying duty time of flight AF447 was 12 h 45, the flight crew was reinforced and increased to three pilots (one captain and two co-pilots).

Flight crew members rest on board

On Airbus A330-203 type aircraft operated by Air France, a rest station intended for the flight crew is installed behind the cockpit. It includes two couchettes.

The reinforcement crew members are present in the cockpit and actively monitor the flight from the departure briefing to FL200 and from the arrival briefing to the gate.

Outside of these flight phases, each member of the flight crew must be able to rest for at least an hour and a half continuously during the flight duty time.

The captain sets the procedures for each member of the crew taking their rest.

The Air France procedures stipulate that before any prolonged absence from the cockpit, the captain indicates the new allocation of tasks. He names the

pilot who replaces him. He specifies the conditions that would necessitate his return to the cockpit.

Note: the ratings of the flight crew members on the accident flight meant that during the captain's rest the substitute first officer had to be the one of the two who held an ATPL. The licences and ratings of crews do not appear in flight dossiers. .

1.17.3 Instruction for use of the on-board weather radar

Operational instructions (General Operations Manual, In-flight Procedures, General Instructions – Foreword, § 6 Use of on-board radar).

The Air France general instructions state that radar watch is obligatory during any flight, except during the day with good visibility and no clouds in sight. The radar image is normally displayed on the two NDs. Correct functioning of the radar is checked during taxiing.

Air France normal procedures - Systems (TU 2.2.34.11-15)

Air France Airbus A330 aircraft are equipped with the Collins WXR700X radar. The radar image is presented on the NDs superimposed on the other information. It can detect precipitations in liquid form greater than 1 mm/h as well as wet hail. Thus, cloud systems made up of drops of water starting from a certain size can be observed but the radar cannot detect dry particles of ice, hail or snow with a diameter less than three centimetres.

In use, the radar beam has a narrow aperture angle of 3.4°, which means that it is necessary to adjust the TILT (angle between the horizontal and the middle of the beam) accurately, in particular according to the maximum range selected at the ND (RANGE): 160 NM for look-ahead, 80 NM for avoidance.

The GAIN adjustment (amplification of the return signal) is normally "calibrated" (in the CAL position) to prevent saturation. However, a manual selection can be made.

A turbulence detection function (for the zones of precipitations in liquid form) is available (in the WX+T or TURB position) in a radius of 40 NM, whatever the RANGE chosen at the ND.

When cruising above 20,000 ft, a slightly downwards adjustment of the TILT is recommended so that the ground echoes only appear on the ND at the limits of the furthest range markers.

Air France Supplementary Aeronautical Manual (MAC)

The MAC is a non-regulatory manual that does not form part of the operations manual. It contains information that the flight crew can use to update and maintain their knowledge. It contains a detailed chapter on the weather radar and its use along with illustrations of the characteristic echoes of dangerous phenomena.

1.17.4 Letters of agreement between air traffic control organisations

1.17.4.1 Letters of agreement between the DAKAR and ATLANTICO control centres

A memorandum of understanding was signed on 16 September 2008 between the Brazilian and Senegalese authorities concerning the coordination procedures between the DAKAR and ATLANTICO control centres. It was in force on the day of the accident. The following points, extracted from the memorandum, should be noted:

The exiting sector must transmit the estimated times of passing of the aircraft to the receiving sector at least twenty minutes before the time of the aircraft's planned passing above the transfer point.

Any revision of the estimated time of the aircraft's planned passing above the transfer point greater than three minutes must be the subject of a new coordination between the exiting and receiving sectors.

The aircraft's crew must establish contact with the receiving sector's controller five minutes before passing above the control transfer point. This contact does not constitute a transfer of the control of the aircraft.

When the receiving sector cannot establish contact with the aircraft's crew in the three minutes following the estimated time of passing above the transfer point. It should inform the exiting sector so that the adequate measures can be taken.

Unless there are specific instructions, the aircraft present in airway UN 873 are transferred between DAKAR and ATLANTICO at point TASIL.

1.17.4.2 Letter of agreement between the DAKAR and SAL control centres

Similar provisions to those mentioned in 1.17.4.1 concerning ATLANTICO and DAKAR are described in the memorandum between the DAKAR and SAL control centres. Nevertheless, the following differences should be noted:

The aircraft's crew must establish contact with the receiving sector's controller (SAL) five minutes before passing above the control transfer point. However, for aircraft flying towards the north and those flying towards the east, the crews must contact the receiving sector ten minutes before the control transfer point to get a transponder code. This contact does not constitute a transfer of the control of the aircraft.

Unless there are specific instructions, the aircraft present in airway UN 873 are transferred between DAKAR and SAL at point POMAT.

1.17.4.3 Memorandum of understanding about the conditions for making a French specialised SAR aircraft available to the Senegalese government at Dakar

The paragraphs below give certain provisions of the memorandum of understanding signed in 1966 between the French and Senegalese governments that are still in force.

A specialised SAR aircraft is made available to the Senegalese government at the Dakar-Yoff aerodrome with a French crew. The crew is completed with Senegalese observers.

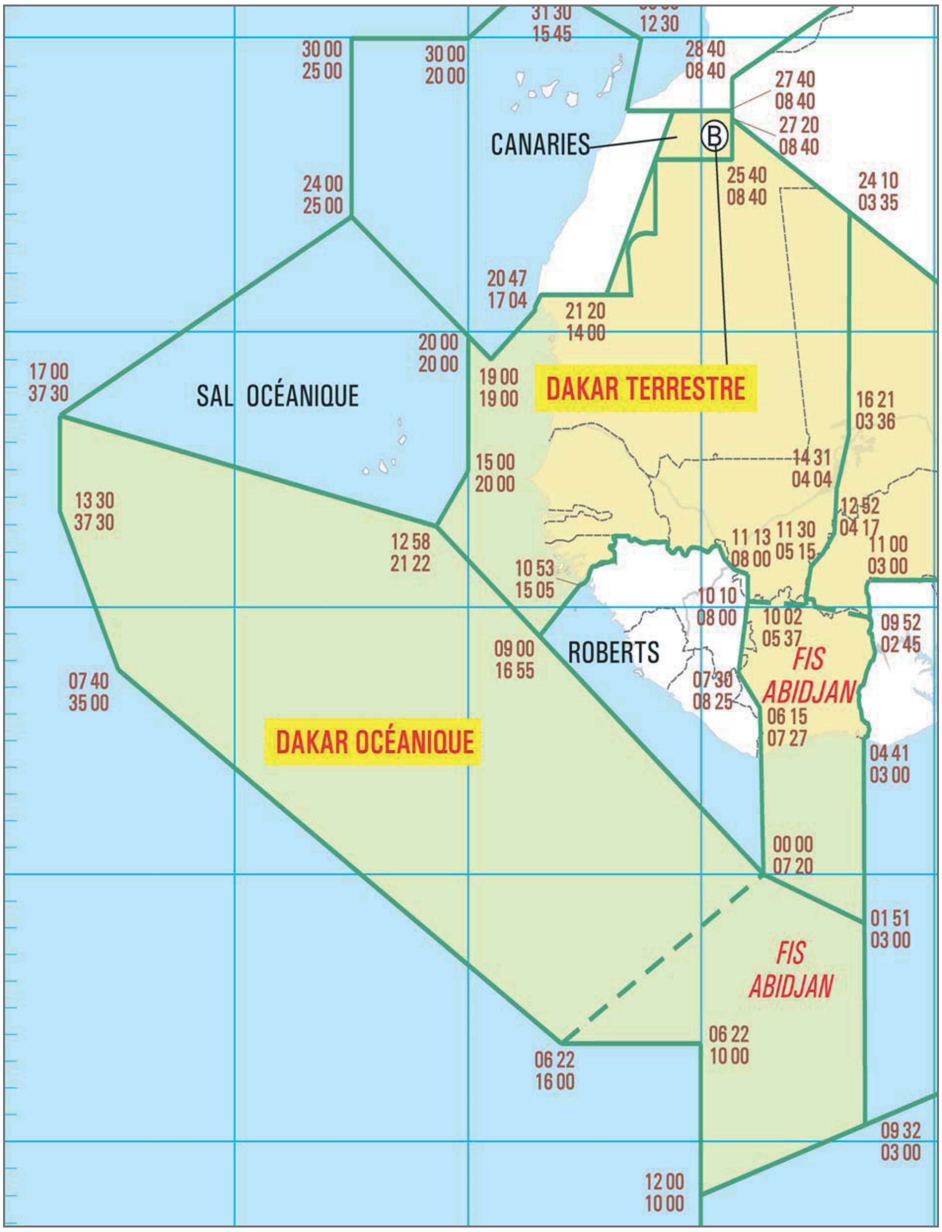
The aircraft made available is of the Breguet Atlantique[19], Falcon 200 Gardian, or Falcon 50 SURMAR type.

The crew is on alert day and night with three hours notice. If the planned mission with the Breguet Atlantique is longer than seven or eight hours, an additional fuel load must be taken and additional time before take-off must be taken into account.

The aircraft is deployed for a SAR mission on request from the SAR Coordination Centre of the Dakar General Staff.

The SAR aircraft's area of action includes the two Dakar land and Dakar ocean search and rescue regions.

The FIR map below is extracted from the Operating Manual of the DAKAR control centre.



[19] The airplane is in fact a Dassault Atlantique 2, a modernised version of the Breguet Atlantique.

1.17.5 Experimental implementation of the ADS-C system at Dakar

The paragraphs below present some provisions of the AIC NR 13/A/08GO of 30 October 2008 issued by Senegal.

Experiment

Within the framework of the improvement of the control services provided to users, the ASECNA has installed an automatic flight data processing system (FPDS) in the Dakar and Niamey en-route control centres. The operational commissioning of the system's functionalities will take place in two phases:

- the first phase, subject of an aeronautical information circular, consists of pre-operational implementation by means of an operational use as a test of the functionalities,
- the second phase concerns the definitive operational implementation, the dates of which will be published by NOTAM.

The system is mainly made up of the following functionalities:

- automated processing of flight plans,
- display of the aerial situation based on the data in the flight plans,
- automatic dependent surveillance,
- ground to air communications by data-link.

The system also includes decision-making support tools for the use of the controller, such as automatic management of strips and the management of system alerts.

Connection procedure in the DAKAR FIR (DAKAR land and DAKAR ocean)

The first connection with the system is made by the crew. For flights entering the DAKAR control region from an FIR not equipped with CPDLC, the DAKAR control centre demands the connection at least twenty minutes before entry into the DAKAR FIR. For flights from a FIR equipped with CPDLC, the first connection must occur five minutes before entry into the DAKAR FIR.

The pre-operational deployment of the system has been effective since 1st November 2008 at 00 h 01. NOTAM A0 115-9 extended the pre-operational period until 29 July 2009.

1.18 Additional information

1.18.1 Events associated with erroneous air speed indications

The BEA asked Airbus, the NTSB, IATA, the DGAC and all French operators to provide information relative to incidents in cruise flight during which a loss or inconsistency of speed indications was observed or reported by the crew. The collection of this information is on-going and analysis of the events already received is in progress. However, this analysis is difficult because of the different nature of data from a flight recorder and the PFR messages.

1.18.2 Brief history of the Pitot probes on Airbus A330 / A340

The conditions under which the probes that equip the Airbus A330/A340 have evolved are being examined by the investigators.

In 2001, following some inconsistent speed problems, it was decided to replace, before the end of December 2003, the Rosemount probes that then equipped the A330 by Goodrich 0851 HL probes or Thales C16195AA probes.

Service Bulletins, issued in 2007 then revised in 2008, recommended the replacement on A330/A340 airplanes of C16195AA probes by C16195BA probes.

On the date of the accident, Airbus A330 / A340 aircraft were equipped with three standards of Pitot probe:

- BF Goodrich Aerospace probes, type 0851 HL,
- Thales Avionics probes of types C16195AA[20] and C16195BA.

[20]It was this type of probe, then produced by Sextant, that was installed on Air France's aircraft on the date of the event.

It should be noted that any improvements that this change of standard could bring to cases of speed inconsistencies encountered in cruise had not been formally established.

In February 2009, at the request of Airbus, Thales carried out a comparative study of the behaviour in icing conditions at high altitude of the two standards, C16195AA and C16195BA. This study concluded that the C16195BA standard performed better, without however it being possible to reproduce on the ground all the conditions that could be encountered in reality.

At the end of April 2009 at the suggestion of Airbus, Air France initiated an in-service assessment on Airbus A330 of the C16195BA standard. The first batch of C16195BA Pitot probes had been received one week before the F-GZCP accident.

1.18.3 Testimony of crews in flight in the vicinity of the accident zone

In order to more closely determine the environment of flight AF447, the BEA made a list of flights close to airway UN 873 during the night of 31 May to 1st June 2009 and asked crews for testimony. Not all of the information requested has been received at present. The testimony summarised hereafter is representative of the information already analyzed.

Flight IB6024

Flight IB6024 (Airbus A340) passed at the level of the ORARO waypoint at FL370 approximately twelve minutes after AF447.

The crew saw AF447 take off while taxiing at Rio de Janeiro. When passing the INTOL waypoint, they encountered conditions typical of the inter-tropical convergence zone. These conditions were particularly severe 70 NM to 30 NM before the TASIL waypoint. They moved away from the route by about 30 NM to the east to avoid cumulonimbus formations with a significant vertical development, and then returned to the airway in clear skies close to the TASIL waypoint. The crew reported they had difficulties communicating with Dakar ATC.

Flight AF459

Flight AF459 (Airbus A330-203) passed at the level of the ORARO waypoint approximately 37 minutes after l'AF447.

The sky was clear but the half-moon, visible to the aft left of the aircraft, did not make it possible to see the contour of the cloud mass distinctly. After flying through a turbulent zone in the head of a cumulus congestus formation at the level of NATAL, without having detected this zone on the radar, the captain selected gain in MAX mode. At about 2 h 00, he observed a first echo that differed significantly depending on whether the radar's gain was in CAL or MAX mode. The TILT was set between -1° and 1.5°. He decided to take evasive action to the west, which resulted in a deviation of 20 NM to the left of the route. During this evasive action, a vast squall line with an estimated length of 150 NM appeared on the screen, which was set to a scale of 160 NM. The echoes were yellow and red when the radar was set with gain on the MAX position and green and yellow when the gain was on the CAL position. No lightning was observed.

ATLANTICO control, informed by the crew of their decision to avoid this squall line by taking evasive action to the east, asked them to return to the airway as soon as they could. This evasive action meant the aircraft flew between 70 and 80 NM to the right of the planned route. In addition, the crew was authorised to climb from FL350 to FL370.

On leaving the ATLANTICO FIR, through the TASIL waypoint, the crew attempted in vain to contact Dakar control on HF on the 5565 KHz and 6535 KHz frequencies, and on the other HF frequencies given in the on-board documentation. Likewise, the attempted ADS-C connection was unfruitful.

The crew returned to the airway around the ASEBA waypoint, that is to say more than 28 minutes after the first theoretical contact with Dakar control. They reported slight turbulence on the edge of the convective zone.

Radio contact was established with Dakar control at about 3 h 45, close to the SAGMA waypoint. The SELCAL test was performed and the controller asked the crew to try to contact AF447. Several attempts were made on various HF frequencies, and then on 121.5 MHz and 123.45 MHz, without any success.

Flight LH507

Flight LH507 (B747-400) preceded flight AF447 by about twenty minutes at FL350.

The crew reported that it flew at the upper limit of the cloud layer and then in the clouds in the region of ORARO. In this zone they saw green echoes on the radar on their path, which they avoided by changing their route by about ten nautical miles to the west. While flying through this zone, which took about fifteen minutes, they felt moderate turbulence and did not observe any lightning. They lowered their speed to the speed recommended in turbulent zones. They saw bright St Elmo's fire on the windshield on the left-hand side. The crew listened on the 121.5 MHz frequency throughout the flight without hearing any message from AF447.

1.18.4 Procedures to be applied in case an unreliable speed indication is detected

On the date of the accident, the operator's procedures mention that the following actions must be carried out from memory by the crew when they have any doubt concerning the reliability of a speed indication and when control of the flight is "affected dangerously":

IAS DOUTEUSE

SI CONDUITE DU VOL AFFECTEE DANGEREUSEMENT,
le CDB annonce "IAS DOUTEUSE", effectuer les actions immédiates suivantes :

PF	AP	OFF
C/P	FD 1 et 2	OFF
PF	A/THR	OFF
PF	POUSSEE / ASSIETTE	AFFICHEES

➤ Avant la réduction de poussée :
- POUSSEE / ASSIETTE .... TOGA / 15°

➤ Après la réduction de poussée :
....
- o Au dessous du FL 100
  - POUSSEE / ASSIETTE .... CLB / 10°
- o Au dessus du FL 100
  - POUSSEE / ASSIETTE .... CLB / 5°

PNF	VOLETS	CONFIG MAINTENUE
PNF	SPEED BRAKES	VERIFIES RENTRES
PNF	TRAIN	RENTRE

Respecter les alarmes décrochage.
LORSQUE LA TRAJECTOIRE EST STABILISEE,
Se référer à la procédure URGENCE / SECOURS non ECAM "VOL AVEC IAS DOUTEUSE / ADR CHECK PROC" (QRH 1.34.xx ou TU 03.02.34.1XX).

If conduct of the flight does not seem to be affected dangerously, the crew must apply the UNRELIABLE SPEED INDICATION / ADR CHECK procedure (see appendix 9).

For information, the "Memory Item" in the Airbus QRH relative to the same fault is shown below in the version in force on the date of the accident.

UNRELIABLE SPEED INDICATION/ADR CHECK PROC

● **If the safe conduct of the flight is impacted :**

MEMORY ITEMS
- AP/FD .... OFF
- A/THR .... OFF
- PITCH/THRUST :
  - Below THRUST RED ALT .... 15°/TOGA
  - Above THRUST RED ALT and Below FL 100 ..... 10°/CLB
  - Above THRUST RED ALT and Above FL 100 ...... 5°/CLB
- FLAPS .... Maintain current CONFIG
- SPEEDBRAKES .... Check retracted
- L/G .... UP

● **When at, or above MSA or Circuit Altitude :**
- Level off for troubleshooting

2. INITIAL FINDINGS

On the basis of the first factual elements gathered in the course of the investigation, the following facts have been established:

- the crew possessed the licenses and ratings required to undertake the flight,
- the airplane possessed a valid Certificate of Airworthiness, and had been maintained in accordance with the regulations,
- the airplane had taken off from Rio de Janeiro without any known technical problems, except on one of the three radio handling panels,
- no problems were indicated by the crew to Air France or during contacts with the Brazilian controllers,
- no distress messages were received by the control centres or by other airplanes,
- there were no satellite telephone communications between the airplane and the ground,
- the last radio exchange between the crew and Brazilian ATC occurred at 1 h 35 min 15 s. The airplane arrived at the edge of radar range of the Brazilian control centres,
- at 2 h 01, the crew tried, without success for the third time, to connect to the Dakar ATC ADS-C system,
- up to the last automatic position point, received at 2 h 10 min 35 s, the flight had followed the route indicated in the flight plan,
- the meteorological situation was typical of that encountered in the month of June in the inter-tropical convergence zone,
- there were powerful cumulonimbus clusters on the route of AF447. Some of them could have been the centre of some notable turbulence,
- several airplanes that were flying before and after AF 447, at about the same altitude, altered their routes in order to avoid cloud masses,
- twenty-four automatic maintenance messages were received between 2 h 10 and 2 h 15 via the ACARS system. These messages show inconsistency between the measured speeds as well as the associated consequences,
- before 2 h 10, no maintenance messages had been received from AF 447, with the exception of two messages relating to the configuration of the toilets,
- the operator's and the manufacturer's procedures mention actions to be undertaken by the crew when they have doubts as to the speed indications,
- the last ACARS message was received towards 2 h 14 min 28 s,
- the flight was not transferred between the Brazilian and Senegalese control centres,

- between 8 h and 8 h 30, the first emergency alert messages were sent by the Madrid and Brest control centres,
- the first bodies and airplane parts were found on 6 June,
- the elements identified came from all areas of the airplane,
- visual examination showed that the airplane was not destroyed in flight; it appears to have struck the surface of the sea in level flight with high vertical acceleration.

List of Appendices

Appendix 1
Meteorological study undertaken by Météo France

Meteorological situation in the tropical atlantic on 1st june 2009

1. General situation

1.1. On the surface of the ocean

1.2. Wind field of lower and mid-altitude layers

1.3. Wind field at altitude

1.4. Evaluation of the tropopause

2. Description of the Inter-tropical Convergence Zone on 1st June 2009

2.1. Position of the Inter-tropical Convergence Zone (ITCZ)

2.2. Storm activity in the ITCZ characterised by météosat 9 infrared
2.2.1. Phenomenology: cumulonimbus and associated phenomena, storm clusters
2.2.2. Advantages and limitations of geostationary infrared imagery
2.2.3. Analysis of the storm activity in the ITCZ over four days (from 30 May to 3 June 2009)

2.3. Analysis of the cluster located on the planned route
2.3.1. Evolution observed between 0 h 00 and 3 h 00
2.3.2. Detailed analysis of the image taken at 2 h 07
2.3.3. Analysis based on "Rapid Developing Thunderstorm" processing
2.3.4. Summary

2.4. Observations by an aircraft equipped with the AMDAR system

3. Conclusions on the analysis of the meteorological situation

1. General situation

Analysis of the situation on a wide scale in the tropical Atlantic is based on the pressure and wind charts produced by the digital global weather forecast models, developed from all of the observations available in real time.

1.1 On the surface of the ocean

Analysis of the pressure field drawn up for the 1st June 2009 at 0 h 00 with the aid of the Météo-France ARPEGE global model, shows the presence of a shallow low at sea level, characterised by pressure gradients of the order of 1 hPa for 1,000 km, which is in accordance with the usual values from the climatology point of view in the Inter-tropical Convergence Zone (ITCZ). The wind field overlaid on the sea level pressures (see Figure 1) confirms the absence of synoptic dynamism for the whole zone between 0 and 10 degrees North inclusive.

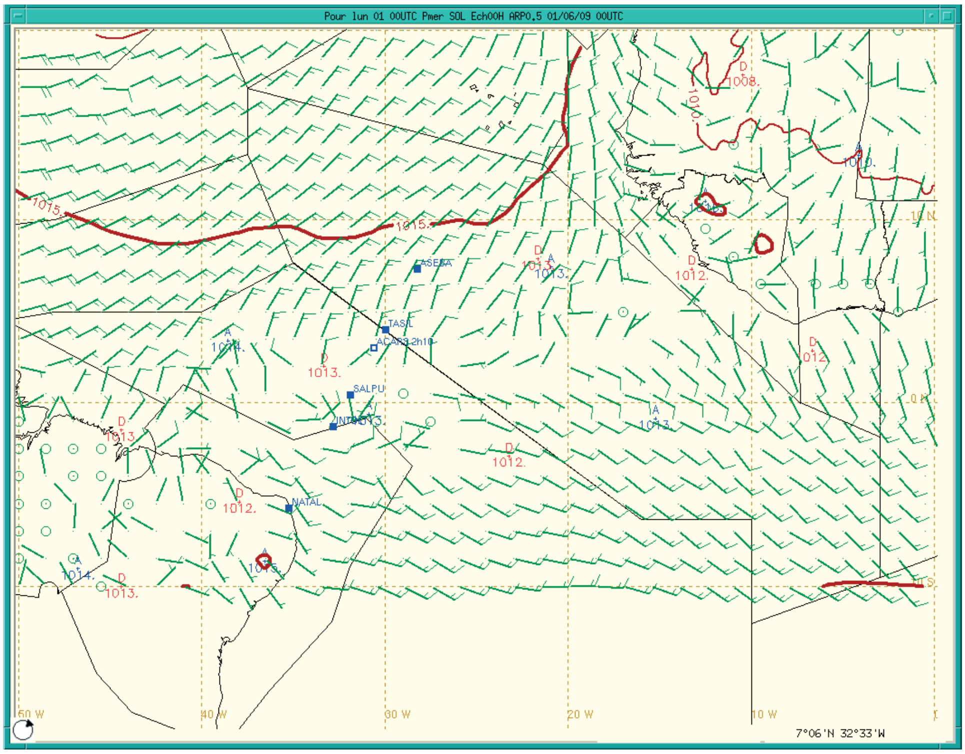


Figure 1: analysis of the wind at 10m and of the pressure at sea level on 01/06/2009 at 0 h 00 (ARPEGE model)

However, even in the presence of relatively low winds, the ITCZ, which corresponds to the "meteorological equator", is the area of a convergence, that occurs in the first 1,000 metres of the atmosphere, between the northern hemisphere trade winds blowing from the north-east and the trade winds of the southern hemisphere blowing from the south east. This convergence generates updraughts that, in an unstable atmosphere, favour the development of powerful cumulonimbus fed with water vapour by exchanges with the ocean surface.

The global models do not make it possible to directly perceive these stormy phenomena and the associated small scale structures, whose life cycle lasts a few hours.

1.2 Wind field of lower and mid-altitude layers

Analysis of the wind fields on the ARPEGE model (see Figure 2) up to the surface isobar 500 hPa (corresponding to around FL180) shows that the winds encountered in the zone were weak – less than 20 knots - and from east to south-east sector.

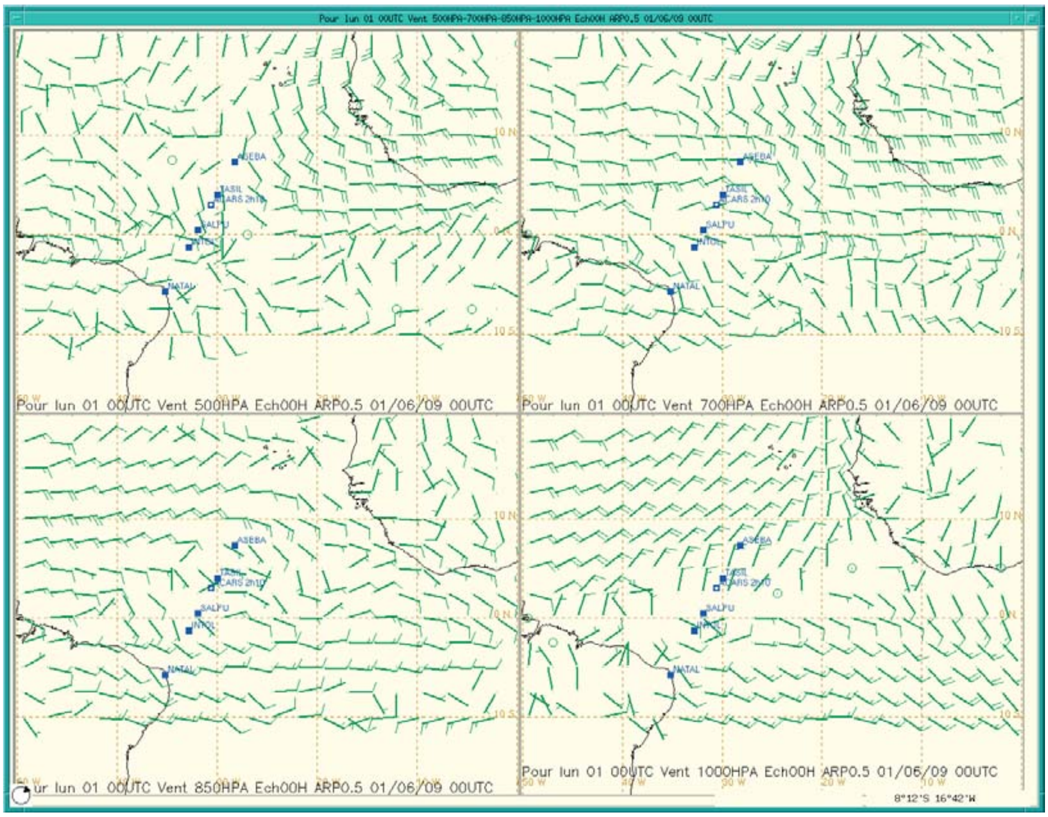


Figure 2: analyses of the wind field
at 1 000, 850, 700 and 500 hPa on 01/06/2009 at 0 h 00 (ARPEGE model)

1.3 Wind field at altitude

Above FL180, the winds were from north sector and remained weak, less than 20 knots between 10° south and 10° north (see the charts below for FL300, 340 and 390).

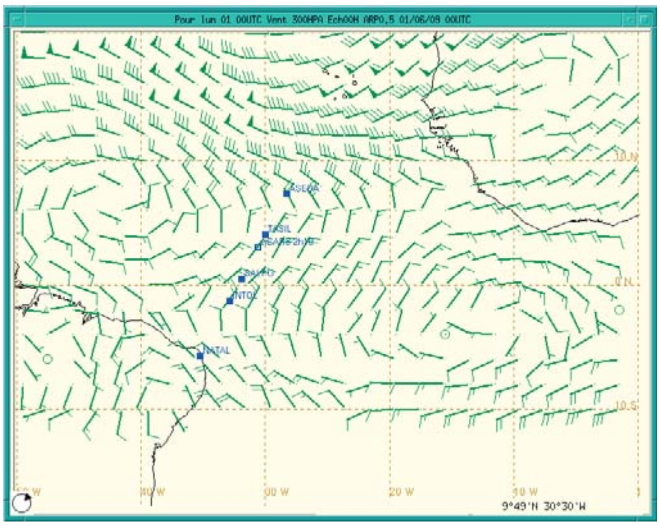


Figure 3: analysis of the wind field
at 300 hPa (FL300) on 01/06/2009 (ARPEGE model)

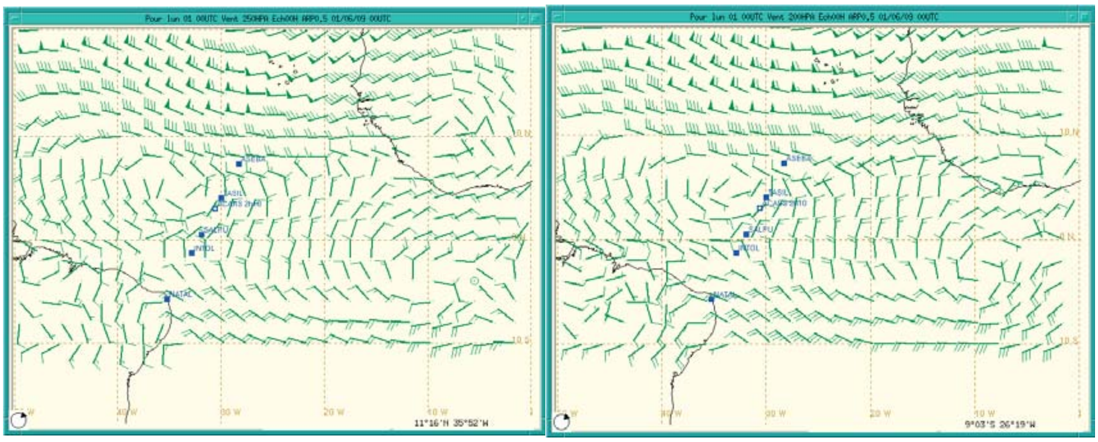


Figure 4 : analysis of the wind field
at 250 hPa (FL340) and 200 hPa (FL390) on 01/06/2009 (ARPEGE model)

1.4 Evaluation of the tropopause

The temperature and height fields (expressed as flight level) of the tropopause analysed by the ARPEGE model show that, in the zone west of the equatorial Atlantic, the temperature of the tropopause was of the order of -80 °C and that its altitude was close to FL520 (figure 5).

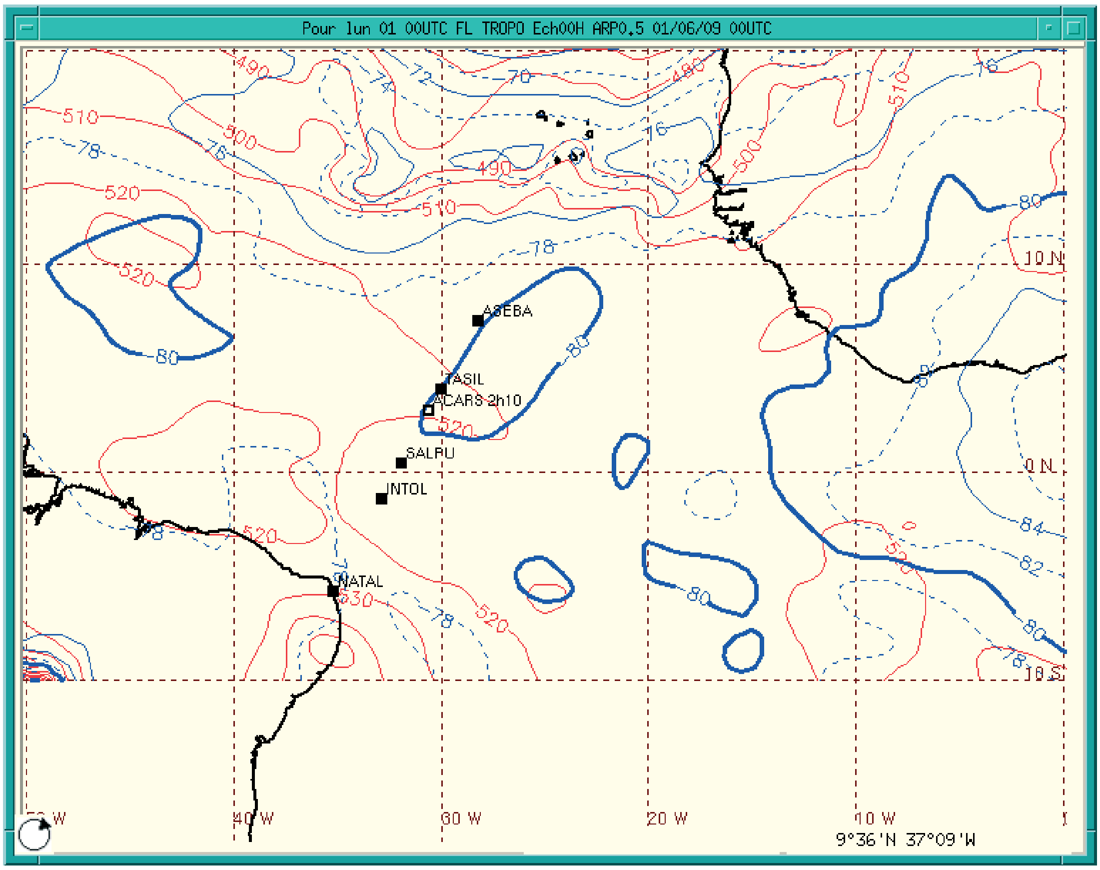


Figure 5: analysis of the temperature field and height (expressed as flight level) of the tropopause on 1st June 2009 at 0 h 00 (ARPEGE model)

2. Description of the inter-tropical convergence zone on 1st June 2009

2.1 Position of the inter-tropical convergence zone

Figure 6 shows the superimposition of the infrared Météosat 9 image dated 1st June 2009 at 2 h 15 and the climatological positions of the ITCZ. The coloured lines correspond to the average positions of the ITCZ in winter and in boreal summer, the latter extending each side of these lines, in a more or less regular manner.

This figure shows that the part of the ITCZ between Brazil and the western Atlantic corresponded to an inter-season position.

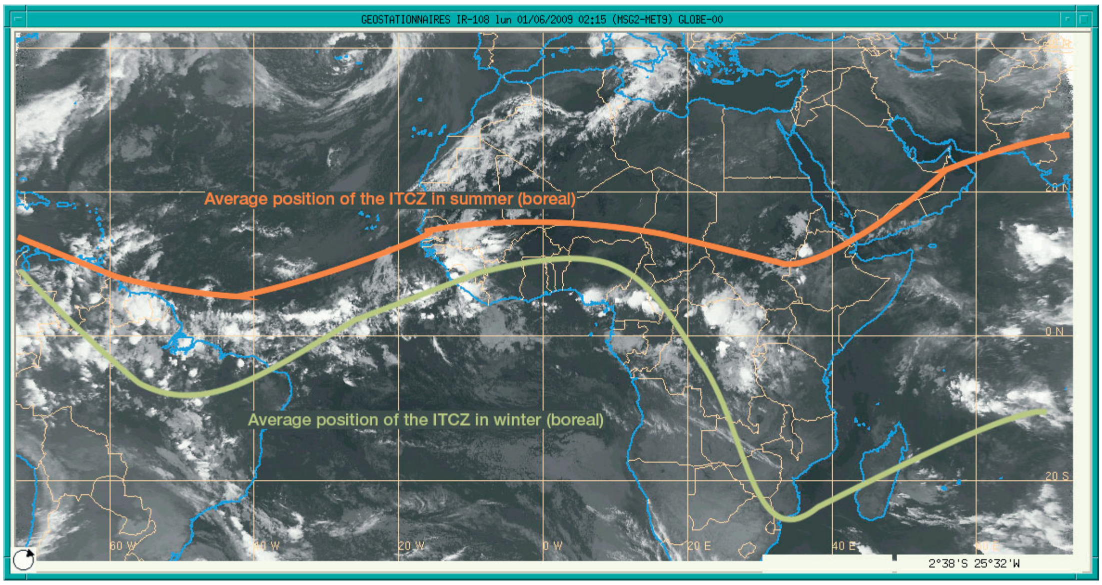


Figure 6: Infrared Météosat 9 image dated 01/06/2009 at 2 h 15
and average climatology positions of the Inter-tropical Convergence Zone

2.2 Storm activity in the ITCZ characterised by Meteosat 9 infrared imagery

2.2.1 Phenomenology: cumulonimbus and associated phenomena, storm cluster

The vertical development of the cumulonimbus is generally limited by the tropopause, whose altitude is between 15 and 18 km in the ITCZ. When the top of a cumulonimbus reaches the altitude of the tropopause, in its phase of maturity, the upper part of the cloud extends horizontally at the level of the tropopause to form "anvils" that then overhang the "tower" of the cloud.

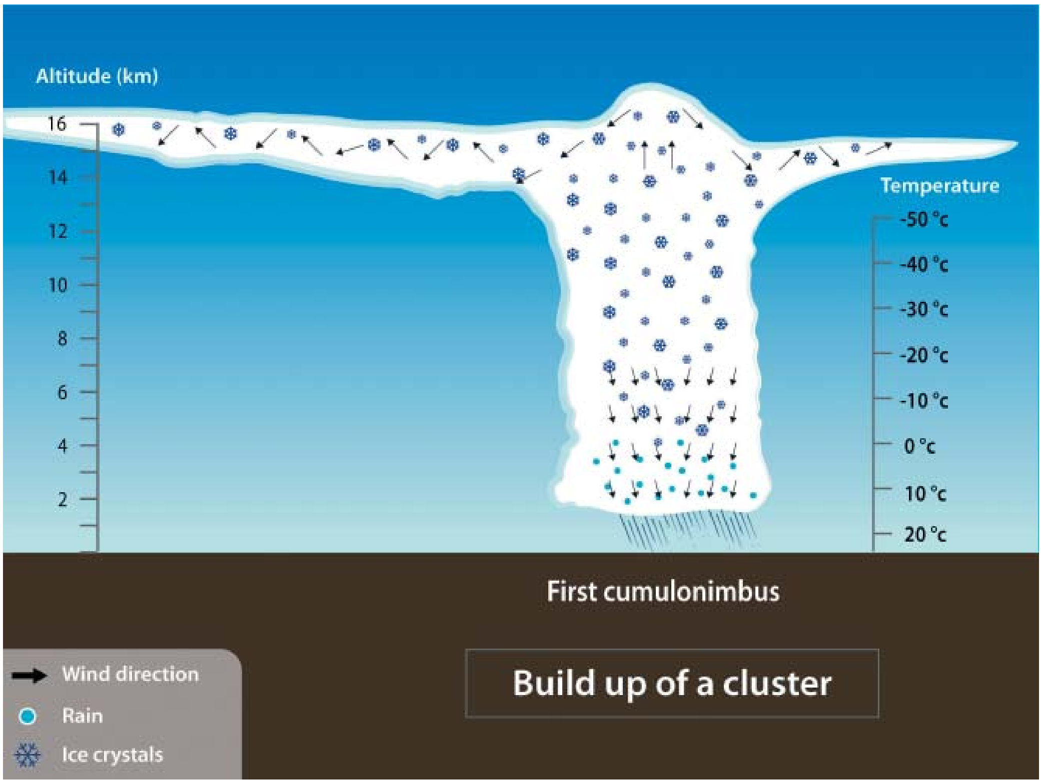
The air that feeds a cumulonimbus spreads and cools when climbing, and at a certain altitude level, when the top of the cloud approaches of the tropopause, it becomes colder than its environment, and is subject to downwards buoyancy that slows then stops its vertical development. Through inertia, the powerful clouds penetrate temporarily beyond the tropopause and their tops are then much colder than their environment: this phenomenon is known as "overshoot", visible on the infrared images, and it makes it possible to characterise most clouds.

The strongest vertical movements are observed in the "tower" of the cumulonimbus in its phase of rapid growth, that is to say before the top reaches the tropopause and the anvil is formed. The upward speeds can then reach 110 km/h and the downward speeds 50 km/h. The vertical speed can thus vary very rapidly inside of the cumulonimbus while crossing its "tower": variations of more than 70 km/h in the space of 2 km have sometimes been observed. This intense turbulence can occur at the flight level of airliners and constitute a danger for them.

The conditions that are the most favourable to icing (presence of super-cooled water) are generally located in the lower central part of the cumulonimbus "tower", in an altitude range where the temperatures are between 0 and -25 °C. However, the icing conditions can persist down to -40 °C or less, that's to say up to around flight level FL350, but ice crystals are encountered at this altitude.

Electrical activity can be strong, with the possibility of the appearance of lightning in the phases of growth or maturity of a cumulonimbus, at any altitude. Lightning can appear between the cloud and the ground, within a cloud or between two clouds, but observation by scientific satellites shows that it is less frequent over the sea than on land.

Cumulonimbus can group together to form storm clusters or convective clusters. The diagrams hereafter illustrate this type of situation.



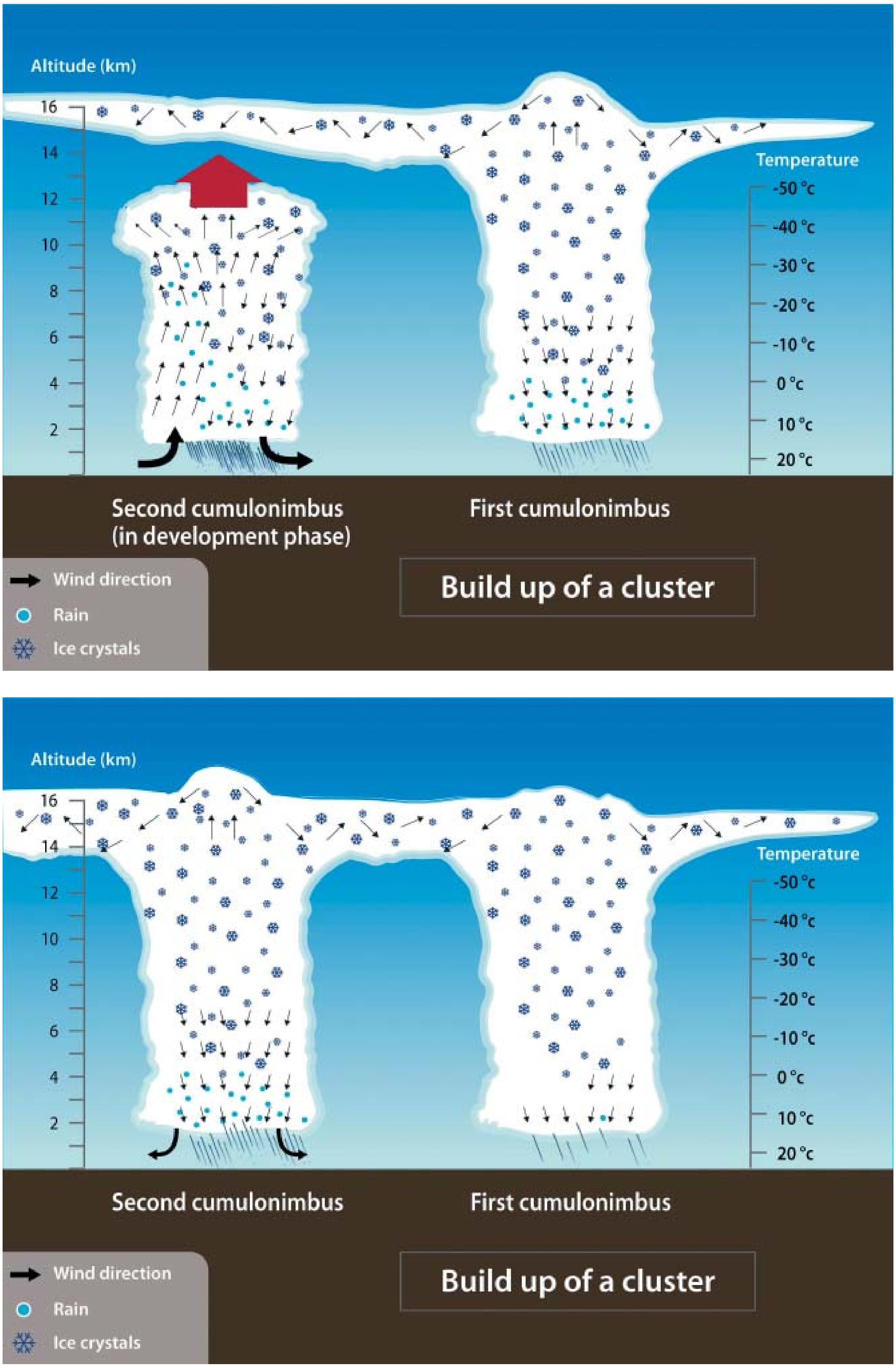


Figure 7: conceptual diagram of the formation of storm clusters (convective)

In the ITCZ, the cruise flight level of airliners is located below the altitude of the "anvils" of the cumulonimbus.

2.2.2 Advantages and limitations of geostationary infrared imagery

The infrared images taken by geostationary satellites make up, over the tropical Atlantic, the main source of information to appreciate the evolution of the storm systems in time and space.

In fact, the images taken every fifteen minutes by Météosat 9 in the infrared ray spectrum, at 10.8 µm, with a resolution of the order of 3 km over the zone, allow an evaluation(1) of the temperature of the top of the clouds from which can be deduced the altitude of the top. Since the more powerful a cumulonimbus is, the higher the altitude of its top is, and the colder its temperature at the top is, infrared imagery makes it possible to a certain degree to appreciate the strength of the cumulonimbus, and to characterise its special extension, the structure and the evolution of the cluster that they form. Imagery can also allow identification of the most notable cumulonimbus, through the thermal signature of the "overshoot" phenomena that are associated with them.

(1)See the Météo-France website http://comprendre.meteofrance.com/pedagogique/dossiers/science_et_techniques/the_satellites_meteorologiques?page_id=2802 for details on the analysis of satellite images.

However, infrared imagery has great limitations: the satellite only observes a dense cloud mass from above, which can result in the juxtaposition of the "anvils" of several cumulonimbus organised in a cluster. Consequently, these images do not allow direct observation of the meteorological conditions at the level of flight located under the cumulonimbus anvils, in the ITCZ. Specifically, the "towers" of cumulonimbus in a rapid growth phase that can produce the most dangerous turbulence can be masked by the anvils of older clouds. However, after their phase of rapid growth, the tops of the strongest cumulonimbus reach the altitude of the tropopause and exceed it temporarily, so that they can generally be identified, later, by infrared imagery thanks to the local very cold signature of their tops.

The complete Météosat 9 images are timed every quarter of an hour at h, h+15, h+30 and h+45. The precise timing of a point of each of the images must take into account the time required for the satellite (12.5 minutes) to scan the terrestrial disk from the South to the North and thus produce a complete image. Thus, the equatorial part of the image is observed in the middle of the scan sequence, or around 8 minutes earlier than the timing recorded for the complete image, h+7, h+22 and h+37, h+52.

2.2.3 Analysis of the storm activity in the ITCZ over four days (from 30 May to 3 June 2009)

At the level of the equatorial Atlantic, the fully developed tops of the cumulonimbus can be identified (up to the tropopause) by the temperatures close to that of the tropopause, of the order of -80° (see figure 5).

Over the period of four days from the 30 May to 3 June 2009, the evolution of the cloudy zones observed was typical of what is often observed in the ITCZ, which extends over an average width of the order of 500 km (see the satellite image animation over four days available on the digital addition to the preliminary report), several clusters of powerful cumulonimbus are visible, of which some

produced infrared signatures comparable or colder than those of the clusters that crossed the planned route of flight AF447, on 1st June 2009 towards 2 h 00.

In the night of 31 May to 1st June 2009, above the ocean, the ITCZ was the seat of notable but discontinuous stormy activity; several convective clusters (multi-cell) are identifiable, separated by the zones of cumulus, stratocumulus and altocumulus.

2.3 Analysis of the cluster located on the planned route

2.3.1 Evolution observed between 0 h 00 and 3 h 00

Between 0 h 30 and 3 h 00, infrared imagery shows a region of development of storm clouds in the ITCZ, north of Fernando de Noronha. The cumulonimbus rapidly formed an extended and organised cluster according to a line oriented west-east. Without being exceptional, the west-east extension of this cluster, which crossed the planned route of flight 447, was sufficiently large, of the order of 400 km (see the satellite image animation over three hours available on the digital addition to the preliminary report).

Towards 2 h 00, this cluster certainly included some of the powerful cumulonimbus associated with of the strong vertical movement zones, but analysis of the infrared images does not show, in itself, temperatures at the tops of clouds significantly colder than that of the tropopause. Analysis of infrared imagery does not make it possible to draw a conclusion on the presence of extremely powerful vertical movements, associated with of the "overshoot" phenomena.

2.3.2 Detailed analysis of the image taken at 2 h 07

On the infrared images presented hereafter, the temperatures of cloud tops that are lower than - 40 °C are coloured. This first "threshold" of -40 °C makes it possible to define the zones for which the clouds had high tops, whether divergent cirrus associated with the cumulonimbus anvils or of their "towers" when they were not masked or when they had temporarily crossed the tropopause.

The convective cluster located on the planned route of flight AF447 is indicated by an oval on Figure 8. bearing in mind the timing system for the Météosat images, this observation occurred at 2 h 07, or around three minutes before the last FMS position communicated by ACARS by flight AF447 at 2 h 10 and around seven minutes before the last ACARS message. No Météosat 9 images coincide with the time of this last message: *the nearest Météosat infrared observations occurred around 7 minutes before and after the last message from flight AF447.*

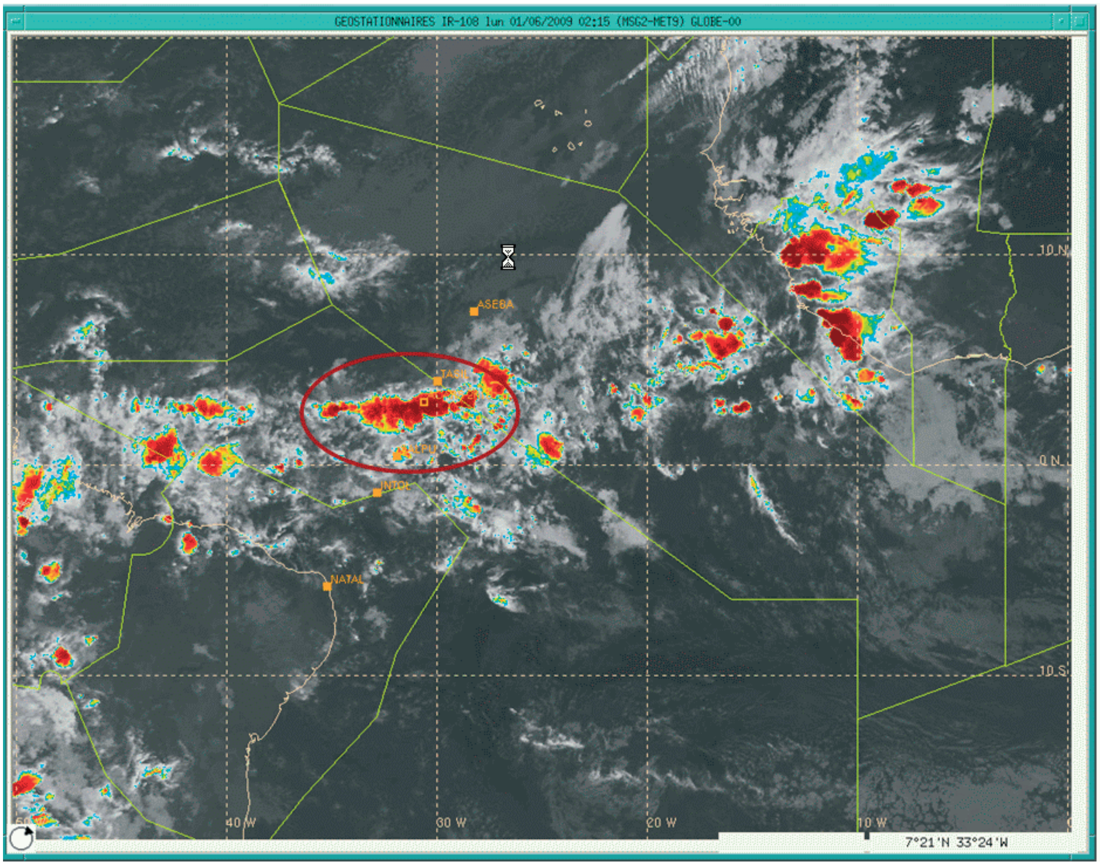


Figure 8: Météosat 9 image, infrared channel 10.8 µ, made on 1st June at 2 h 07, with, in colour, the temperatures at the cloud tops colder than -40 °C. This thresholding allows a first characterisation of the convective clusters.

The analysis then continues by adapting colder and colder thresholds, to characterise the zones that are smaller and smaller, where the tops of the clouds are higher and higher. Figures 9, 10, 11 and 12 that follow were obtained from thresholds of -50 C, -60 C, -70 C and -75 C respectively. The last position information communicated by the airplane at 2 h 10 (point named "ACARS 2 h 10") is indicated on these satellite images(2).

(2)The pixels of the satellite image have a resolution of 3 km and are positioned with precision of the order of a km, much lower than that of the GPS.

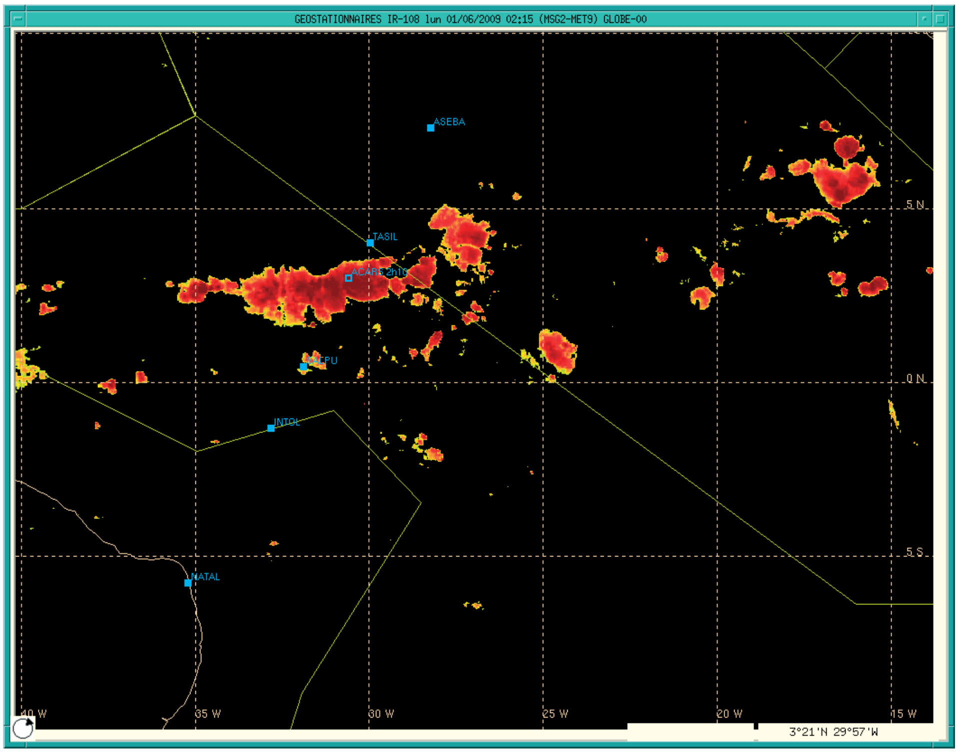


Figure 9: Infrared Météosat 9 image taken on 1st June around 2 h 07 "thresholded", with masking of the temperatures above -50 °C

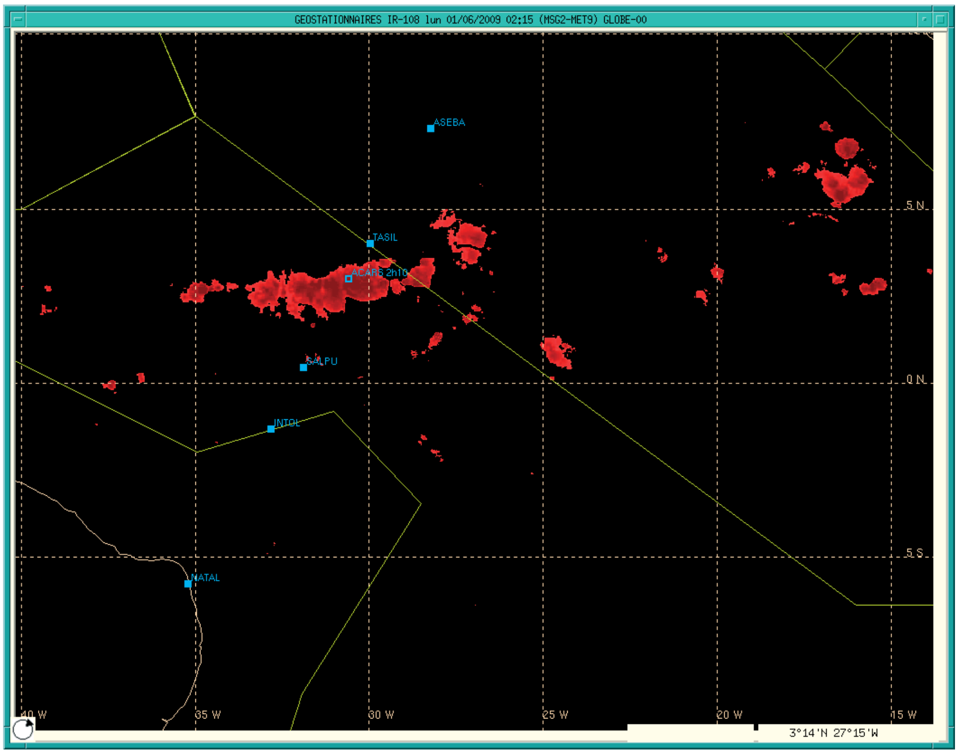


Figure 10: infrared Météosat 9 image taken on 1st June around 2 h 07, "thresholded", with masking of the temperatures above -60 °C

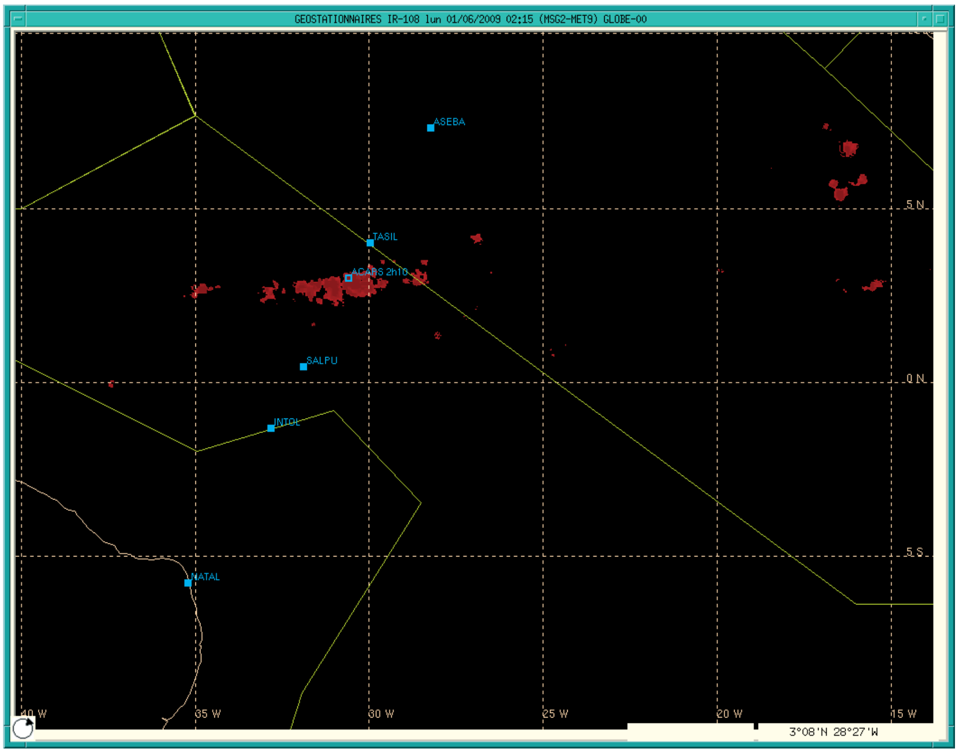


Figure 11: infrared Météosat 9 image taken on 1st June at 2 h 07, "thresholded", with masking of the temperatures above -70 °C

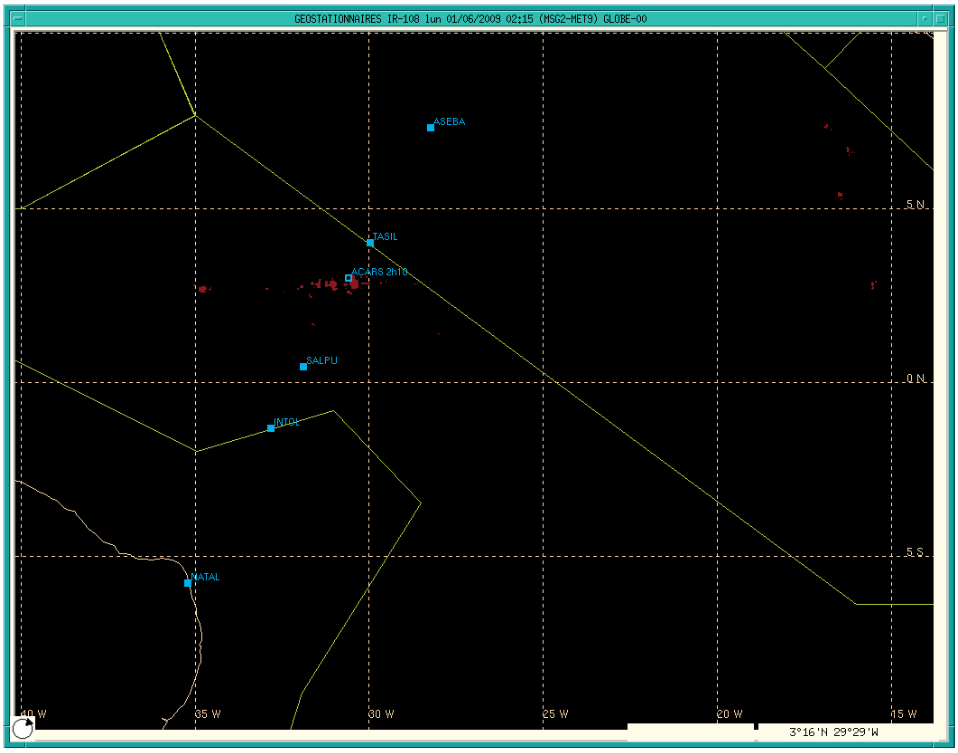


Figure 12: infrared Météosat 9 image taken on 1st June at 2 h 07, "thresholded", with masking of the temperatures above -75 °C

It is notable that at 2 h 07 the coldest temperatures are of the order of -75 °C to -80 °C, while the tropopause was located between FL500 and FL520, with a temperature close to - 80 °C : some of the cumulonimbus in the cluster reached the altitude of the tropopause and their stage of maturity, but imagery does not reveal any exceptional vertical development from the climatology point of view, which would be characterised by an "overshoot".

2.3.3 Analysis based on “Rapid Developing Thunderstorm” processing

The "Rapid Developing Thunderstorm" (RDT) processing of Météosat 9 imagery, whose results are presented hereafter, made it possible to follow the formation and the development of the cluster of cumulonimbus identified in figure 8, through the variations in top temperatures and of the horizontal extension of the surface that they occupied.

The processing first allowed relatively homogeneous top temperature zones to be defined, defined by the black contour lines, in figure 13. These zones were then subject to processing to detail the evolution of their morphology and the top temperatures of the cumulonimbus present: each zone was characterised by a set of parameters whose evolution was followed over a period of fifteen minutes. The interpretation of the evolution of the parameters took into account the possibility for these homogeneous zones to merge or to break up over time.

Characterisation of the cluster à 2 h 07

Figure 13 illustrates the results of the processing of the image taken at 2 h 07. The processing defined several homogeneous zones, of which the coldest, to the centre of the image, was the most extensive, and constituted the essential part of the cluster: in the following, this zone is identified as the "cluster". Its characteristic parameters are defined by the box.

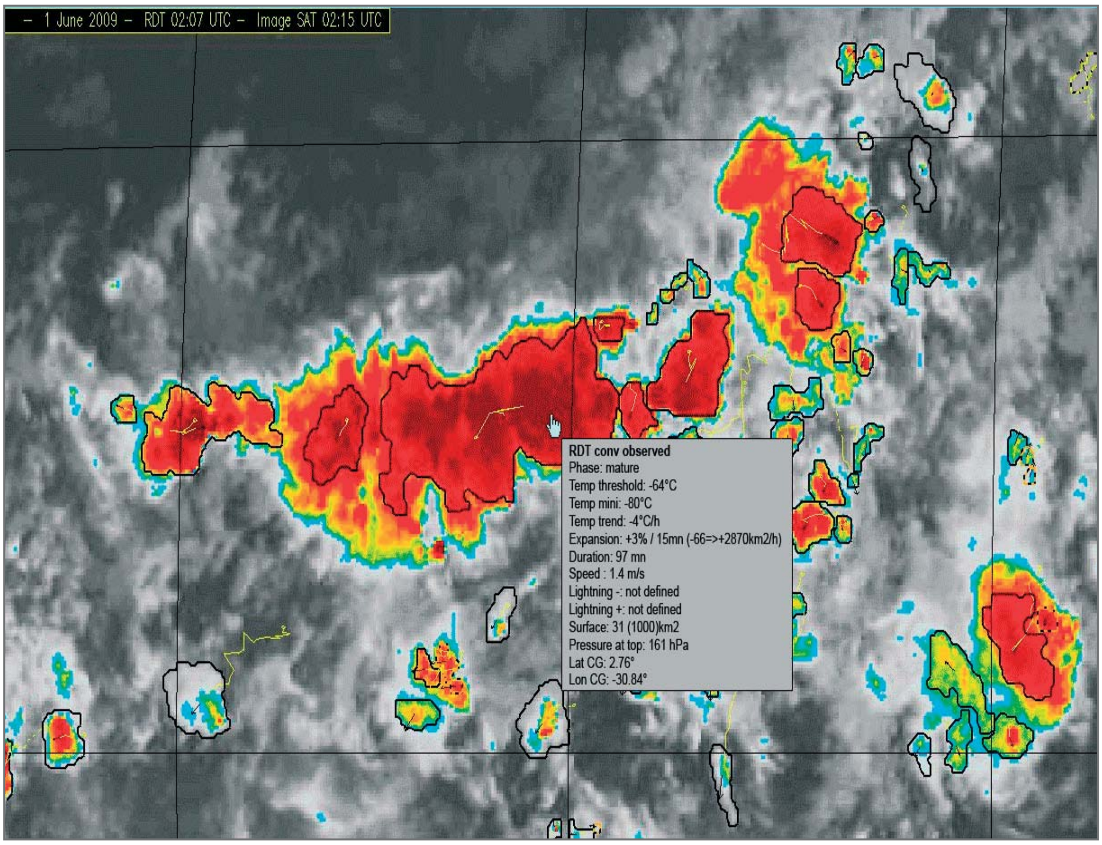


Figure 13: Météosat image taken on 1st June 2009 at 2 h 07, processed by the RDT method. The stormy zones are identified and defined by the black contours, and their parameters (defined) can be followed over time, from one image to the other, in 15 minutes steps.

The two graphs in figure 14 analyse the evolution over time, from 0 h 07 to 2 h 07, of the main observable parameters characteristic of the cluster:

- at the top, the evolution over time of the morphology of the cluster, assessed by the evolution of the surface (in thousands of square kilometres) occupied by those of the cumulonimbus whose top temperatures were lower than various thresholds,
- below, the evolution over time of the lowest top temperature observed within the cluster, corresponding to the signatures of the most developed cumulonimbus.

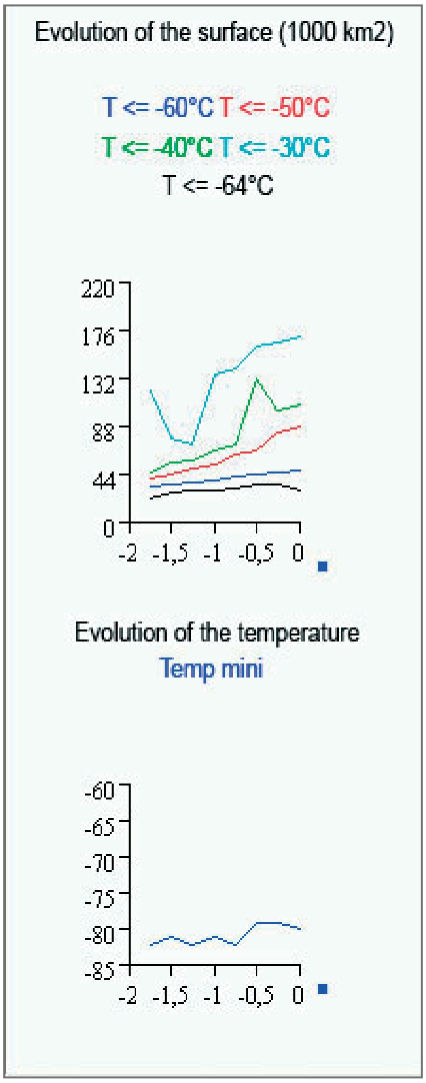


Figure 14: Evolution of the characteristic parameters of the zone identified by the pointer and box in figure 13, which constitutes the main part of the cluster. The time, the lower scale, is defined in relation to 2 h 07, with a scale in hours.

The curves of the first diagram in figure 14 show that the cluster was still expanding horizontally at 2 h 07, the surfaces of the top temperatures zones lower than each of the still rising thresholds, except for the colder threshold (< - 64 °C), for which a surface stagnation or slight fall is noticed.

On the lower diagram, the blue curve indicates that the cumulonimbus present within the cluster reached the level of the tropopause for at least 1 h 30, thus before 0 h 37.

All of these characteristics are consistent with the evolution of a cluster that extended by spreading of the cumulonimbus anvils to the area of the tropopause, but whose strongest cumulonimbus completed their development.

Formation of the cluster

Analysis of the observations previous to 2 h 07 shows that this cluster was the result of the merging of four pre-existing clusters, occurring around 1 h 30 before the planned time for flight AF447 to pass, as illustrated in Figure 15.

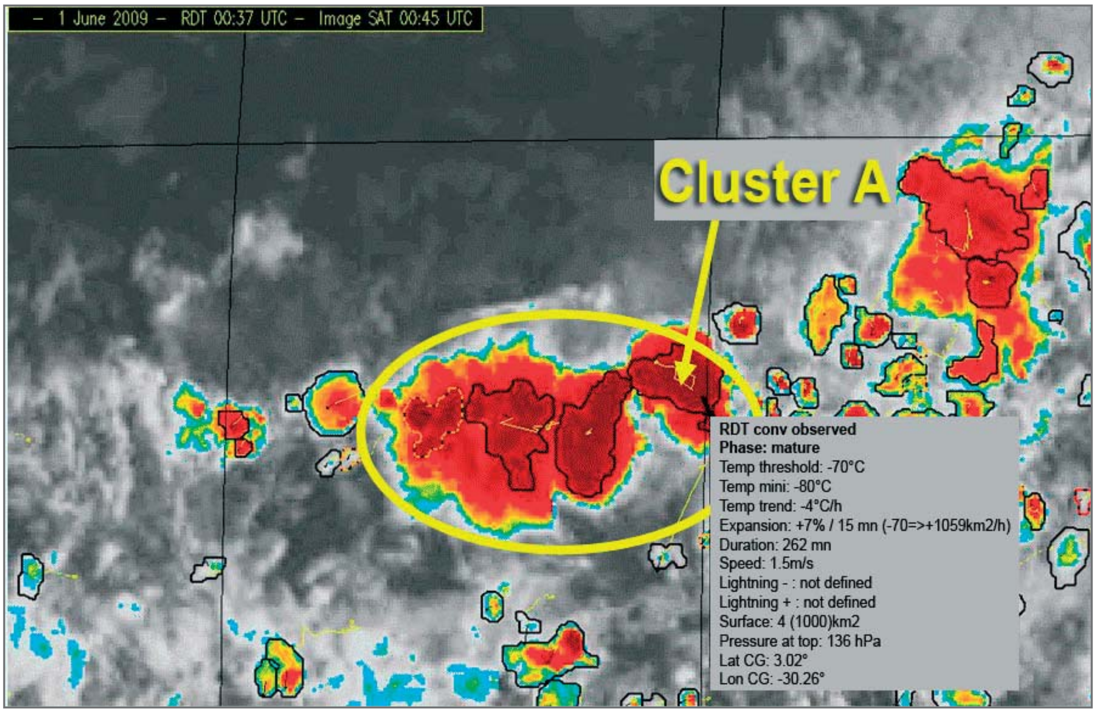


Figure 15: presence of four clusters at 0 h 37 whose merging led to the cluster identified in Figure 13

The development of the cluster marked A, located furthest East, was the most noticeable in this period, as Figure 16 shows, which presents the evolution of its characteristics. Its top temperatures cooled suddenly, which indicates it was the seat of a very rapid vertical development, more than 3 h hours 30 before the arrival of flight AF447. Then, its overall activity was maintained with some cumulonimbus developed up to the tropopause.

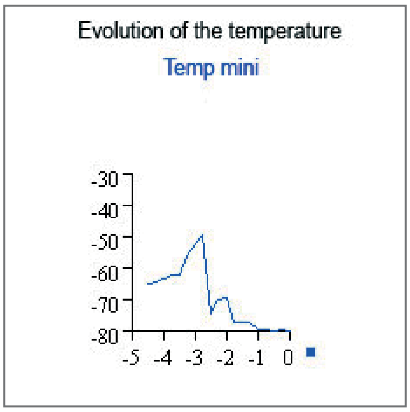


Figure 16: evolution of the top temperature of the cluster marked A on figure 15. The time on the lower scale is defined in relation to 0 h 37

2.3.4 Summary

Analysis of infrared Météosat 9 imagery indicates that the cluster that was crossing the planned flight path of the airplane towards 2 h 10, had formed 1 h 30 previously by the merging of four pre-existing clusters that contained some fully developed cumulonimbus. The most active of these four clusters, located the furthest East, had developed suddenly 3 h 30 previously.

Towards 2 h 10, the cluster resulting from of this merging was still in its horizontal extension phase, probably spreading of the anvils cumulonimbus that were already at maturity. Imagery suggests that the strongest cumulonimbus that made it up completed their development, but the presence of convective "towers" under their anvils was very probable, even if the imagery does not make it possible to confirm this, in the absence of a thermal signature of "overshoot" phenomena.

2.4 Observations by an aircraft equipped with the amdar system

Some airliners are equipped with AMDAR systems (Aircraft Meteorological Data Relay) that allow them to make observations of wind, temperature and, in certain cases, of turbulence, then to transmit them in real time to meteorological centres, in the form of a coded AMDAR message. The message only identifies the transmitting aircraft by a code that does not make it possible to identify either the airline or the flight.

These messages are transmitted in more or less real time to the meteorological services (97% of the messages are sent in 90 minutes). The wind and temperature observations are used to feed the digital weather forecast models.

In cruise, the frequency of the measurements is of the order of 7 to 8 minutes. The observations made all along the flight path relate directly to the conditions at the flight level, but do not, unlike infrared imagery, make it possible to appreciate the conditions outside of the flight path, nor the three dimensional extension of the phenomena encountered.

During the night of 31 May to 1st June, an airplane equipped with the AMDAR system followed a route apparently similar to that of flight AF447, passing in the vicinity of the same storm clusters, around 30 minutes earlier, at flight level FL325. This aircraft only transmitted the wind and temperature measurements.

Figure 17 below indicates the positions of this airplane until 2 h 06 UTC (the position most to the north of the flight path in the middle of the image), overlaid with the Météosat infrared 9 image taken towards 1 h 52 UTC, with a threshold to identify the cluster and the cumulonimbus, using the same classes of colour as for figure 8. The observation position that is most representative of the cluster is that at 1 h 44, indicated by a square.

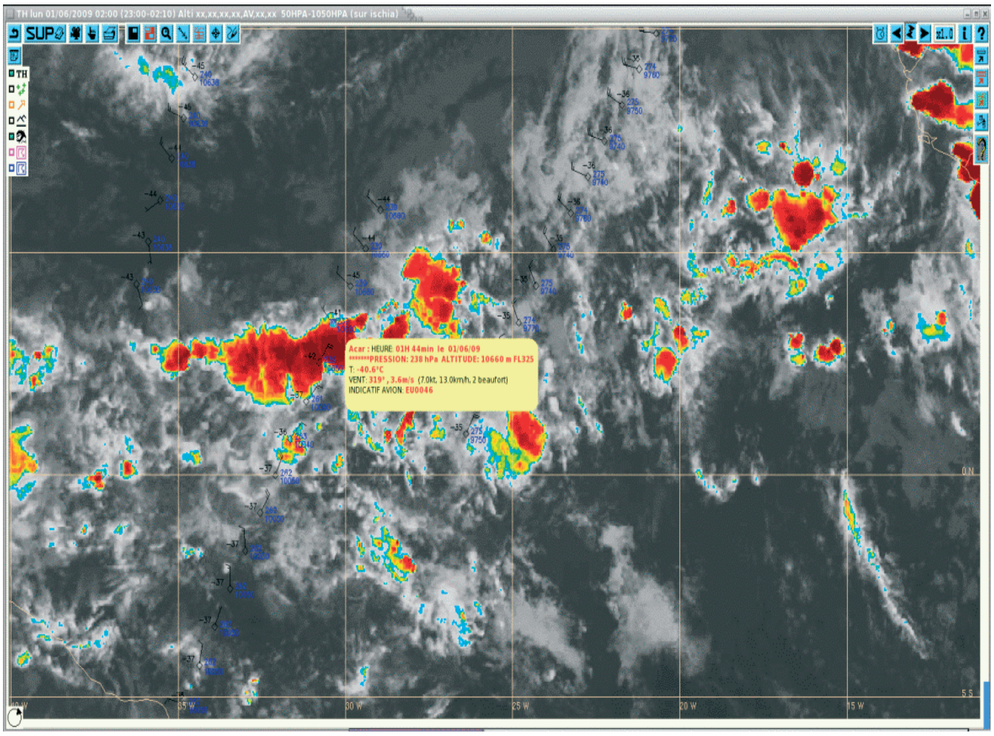


Figure 17: flight path of an airplane equipped with the AMDAR system until 2 h 06 UTC overlaid with the Météosat 9 infrared observation, with a threshold, at 1 h 52 UTC

A variation of the temperature and of the wind measured before and after the passage of the cluster is observable. The differences in temperature are the only significant elements, but can be explained by the airplane's change in flight level, from level FL330 to the south of the cluster to level FL350 after crossing it.

These AMDAR observations do not provide anything notable for the analysis undertaken based on the infrared imagery, which is much more representative of the storm phenomena encountered on the flight path of flight AF 447.

On the other hand, the superimposition of the flight path of the airplane and of the infrared Météosat 9 images shows that the aircraft crossed the convective cluster in a zone where the top temperatures of the cumulonimbus were cold, comparable to those observed a few minutes later.

3. Conclusions on the analysis of the meteorological situation

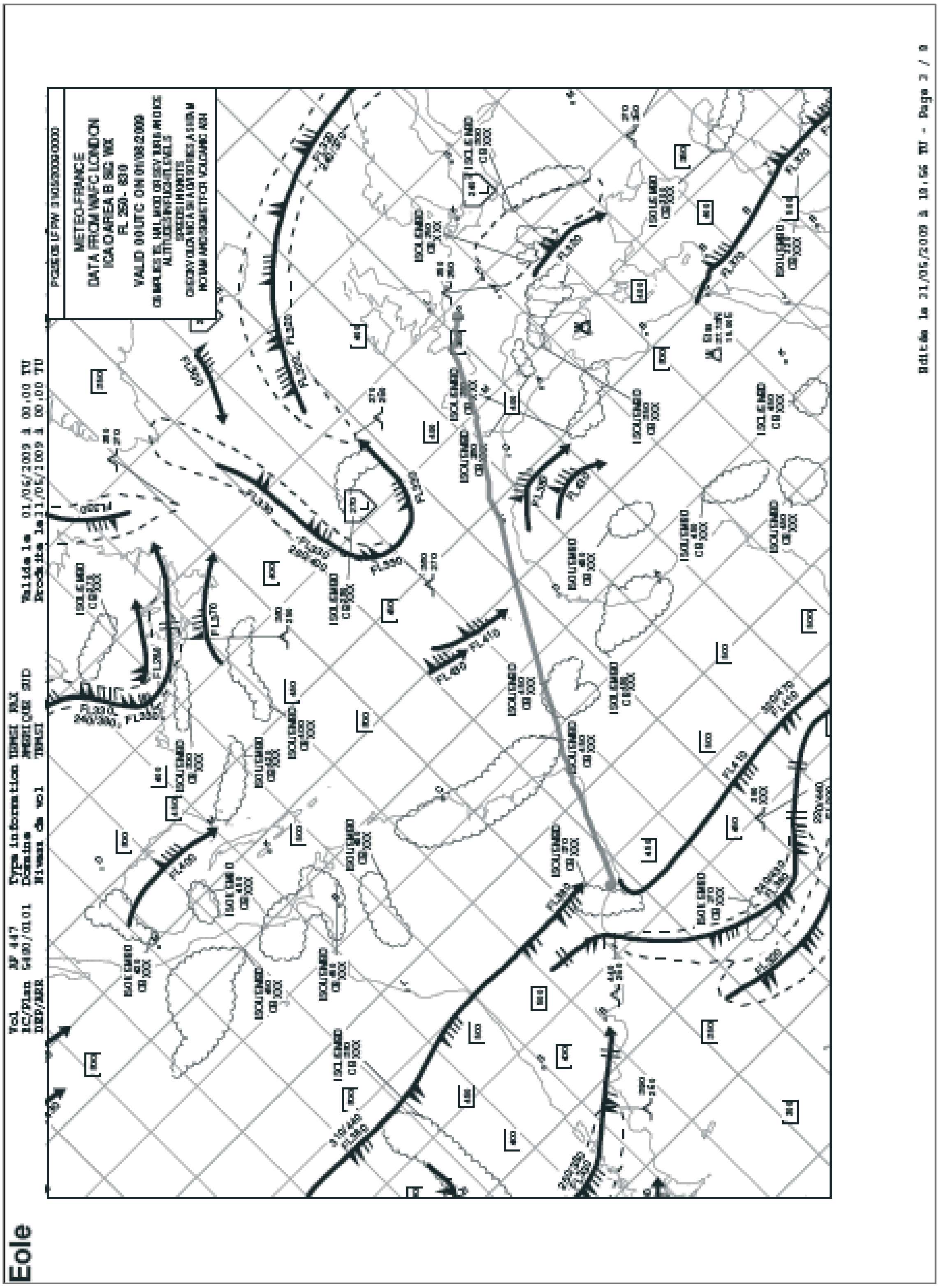
From a climatology perspective, the general conditions and the position of the Inter-tropical Convergence Zone over the Atlantic were normal for a month of June. The clusters of cumulonimbus characteristic of this zone were indeed present, with significant spatial heterogeneity and a life of a few hours.

The infrared images taken every 15 minutes by the Météosat 9 geostationary satellite are the best source of information to appreciate the evolution of these clusters, but they do not make it possible to directly observe the conditions encountered at the flight level. Further, the two most representative images were taken around 7 minutes before and after the last ACARS message from flight AF 447.

Analysis of infrared imagery does not allow any conclusion as to the exceptional character of the storm activity in the area where flight AF447 disappeared, but it shows, on the planned flight route, the existence of a cluster of powerful cumulonimbus, identifiable from 1 h 30 UTC. This cluster resulted from the merging of four smaller clusters and its extension from west to east over around 400 kilometres is quite noticeable.

If the analysis of the imagery leads one to think that, towards 2 h 00 UTC, the cumulonimbus that made up this cluster had for the most part already reached their stage of maturity, it is very likely that some were the seat of notable turbulence at the flight level. The presence of significant electrical activity at the flight level was possible, but the presence of super-cooled water at FL350 was unlikely and would necessarily have been limited to small quantities.

Appendix 2
TEMSI SOUTH AMERICA chart for 1st June at 0 h 00 between FL 250 and 630



Appendix 3
Transcript of radio communications concerning flight AF447

The following radio communications transcripts were supplied by Brazil.

The abbreviations used mean:

- ACC-BS: BRASILIA ATC centre
- ACC-RE: RECIFE ATC centre
- ACC-AO: ATLANTICO ATC centre

Exchanges between RECIFE and flight AF447

11 HORA	12 OPR QRG	13 ANV. ÓRGÃO	14 TEXTO
23:19:27	126,5	AFR 447	-Recife Center good evening, AIR FRANCE FOUR FOUR SEVEN level three five zero.
23:19:34	"	ACC-RE	-FOUR FOUR SEVEN good evening squawk ident maintain three five zero under radar surveilance.
23:19:43	"	AFR 447	-Three five zero squawk ident AIR FRANCE FOUR FOUR SEVEN.
23:28:41	"	ACC-RE	-AIR FRANCE FOUR FOUR SEVEN, AIR FRANCE FOUR FOUR SEVEN say me your mach number speed and selcal code.
23:28:52	"	AFR 447	-Mach number will be eight two and selcal Charlie Papa Hotel Quebec.
00:00:35	"	ACC-RE	-AIR FRANCE FOUR FOUR SEVEN, AIR FRANCE FOUR FOUR SEVEN cal now frequency one two five decimal four five.
00:00:41	"	AFR 447	-One two five four five, bye bye AIR FRANCE FOUR FOUR SEVEN.
00:00:57	125,45	AFR 447	-Good evening AIR FRANCE FOUR FOUR SEVEN level three five zero.
00:01:04	"	ACC-RE	-FOUR FOUR SEVEN three five zero squawk ident under radar control.
00:01:09	"	AFR 447	-Roger AIR FRANCE FOUR FOUR SEVEN.
00:32:31	"	AFR 447	-Recife AIR FRANCE FOUR FOUR SEVEN.
00:32:36	"	ACC-RE	-AIR FRANCE FOUR FOUR SEVEN go ahead.
00:32:43	"	AFR 447	-AIR FRANCE FOUR FOUR SEVEN squawk ident.
00:32:47	"	ACC-RE	-Ok AIR FRANCE FOUR FOUR SEVEN but squawk ident for AIR FRANCE FOUR FIVE NINE, maintain three five zero radar control.
00:35:15	"	ACC-RE	-FOUR FOUR SEVEN Recife Center.

00:35:56	"	ACC-RE	-FOUR FOUR SEVEN call me frequency one two eight decimal seven and secundary, correction, secundary one three four decimal eight.
00:36:12	"	AFR 447	-Two eight seven, one three four eight.
00:36:15	128,7	AFR 447	-Recife, AIR FRANCE FOUR FOUR SEVEN level three five zero.
00:36:40	128,7	ACC-RE	-AIR FRANCE FOUR FOUR SEVEN good evening radar control, maintain flight level three five zero, over INTOL intersection contact Atlantico eitchef (HF) six five three five or five five six five, until there maintain this frequency.
00:36:55	"	AFR 447	-Six five three five and five five six five for eitchef (HF) frequency, AIR FRANCE FOUR FOUR SEVEN.
01:14:23	"	AFR 447	-...(Ininteligível)...FOUR FOUR SEVEN.
01:14:31	"	AFR 447	-AIR FRANCE FOUR FOUR SEVEN, we cheking FEMUR at zero one one three, level three five zero, we contact Atlantico eitchef....
01:14:44	"	ACC-RE	-Negative, after...over INTOL...(Ininteligí- vel)...
01:14:54	"	AFR 447	-After INTOL, AIR FRANCE FOUR FOUR SEVEN.
01:31:36	"	ACC-RE	-AIR FRANCE FOUR FOUR SEVEN Recife Center.
01:31:42	"	AFR 447	-AIR FRANCE FOUR FOUR SEVEN.
01:31:44	"	ACC-RE	-AIR FRANCE FOUR FOUR SEVEN Atlantico six six four nine back up five five six five, after TASIL six five three five.
01:32:01	"	AFR 447	-I undestood six six four nine and five five six five, six five three five.
01:32:10	"	ACC-RE	-Six five three five only after TASIL with FIR DAKAR.
XXXXXXX	XXXXXX	XXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Exchanges between ATLANTICO and flight AF447

11 HORA	12 OPR QRG	13 ANV.	14 TEXTO
01:33:25	TASA-LP	AFR 447	-Atlântico, Atlântico, AIR FRANCE FOUR FOUR SEVEN calling Atlântico on six six.
01:35:06	"	AFR 447	- Atlântico, Atlântico, AIR FRANCE FOUR FOUR SEVEN calling Atlântico on six six.
01:35:12	"	ACC-AO	-AIR FRANCE FOUR FOUR SEVEN, Atlântico go ahead.

01:35:15	"	AFR 447	-AIR FRANCE FOUR FOUR SEVEN, by checking INTOL zero one three three, level three five zero, SALPU zero one four eight, next ORARO zero two zero zero, selcall check Charlie Papa Hotel Quebec.
01:35:38	"	ACC-AO	Acionamento do código SELCALL
01:35:43	"	AFR 447	-AIR FRANCE FOUR FOUR SEVEN, thank you.
01:35:46	"	ACC-AO	-Welcome, maintaing flight level three five zero, say your estimate TASIL?
01:35:53	"	ACC-AO	-Say your estimate TASIL?
01:35:59	"	ACC-AO	-AIR FRANCE FOUR FOUR SEVEN estimate TASIL?
01:36:14	"	ACC-AO	-AIR FRANCE FOUR FOUR SEVEN say your estimate TASIL?
XXXXXX	XXXXXX	XXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Exchanges between ATLANTICO and flight AF447

11 HORA	12 OPR QRG	13 ANV. ÓRGÃO	14 **TEXTO**
23:07:15	CTA-07 ASS	ACC-BS	-...o AIR FRANCE QUATRO QUATRO SETE por FLIRT.
23:07:17	"	ACC-RE	-QUATRO QUATRO SETE nível três cinco zero, deixa eu ver o limite aqui...INTOL.
23:07:22	"	ACC-BS	-INTOL.
XXXXXX	XXXXXXXX	XXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXX
01:04:37	CTA-11 ASS	ACC-RE	-...já tem o AIR FRANCE QUATRO QUATRO SETE em INTOL?
01:04:42	"	ACC-AO	-Não, ainda não.
01:04:44	"	ACC-RE	-Ah, tá ok.
XXXXXX	XXXXXXXX	XXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXX
01:12:53	CTA-11 ASS	ACC-RE	-....você tem o AIR FRANCE QUATRO QUATRO SETE?
01:12:56	"	ACC-AO	-Não, QUATRO QUATRO SETE ainda não.
01:12:58	"	ACC-RE	-INTOL. Não NÉ?
01:13:00	"	ACC-AO	-Tá bom.
XXXXXX	XXXXXXXX	XXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXXX
01:14:58	CTA-11 ASS	ACC-RE	-Região de INTOL.
01:15:00	"	ACC-AO	-AIR FRANCE QUATRO QUATRO SETE já chegou.

01:15:02	"	ACC-RE	-Aos trinta e dois mantendo três cinco zero.
01:15:05	"	ACC-AO	-Obrigado.
01:15:07	"	ACC-RE	-Falou.
XXXXXX	XXXXXXXX	XXXXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Exchanges between ATLANTICO and DAKAR to coordinate flight AF447

11 HORA	12 OPR QRG	13 ANV. ÓRGÃO	14 TEXTO
01:35:26	"	ACC-AO	-Copy AIR FRANCE FOUR FOUR SEVEN.
01:35:29	"	ACC DAKAR	-FOUR FOUR SEVEN.
01:35:32	"	ACC-AO	-AIR FRANCE FOUR FOUR SEVEN, TASIL zero two two zero
01:35:36	"	ACC DAKAR	-Zero two two zero.
01:35:37	"	ACC-AO	-Flight level three five zero mach point eight two, and the...
01:35:45	"	ACC DAKAR	-Ok, call you back, please.
01:35:46	"	ACC-AO	-Ok, ok, no problem.
XXXXXX	XXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

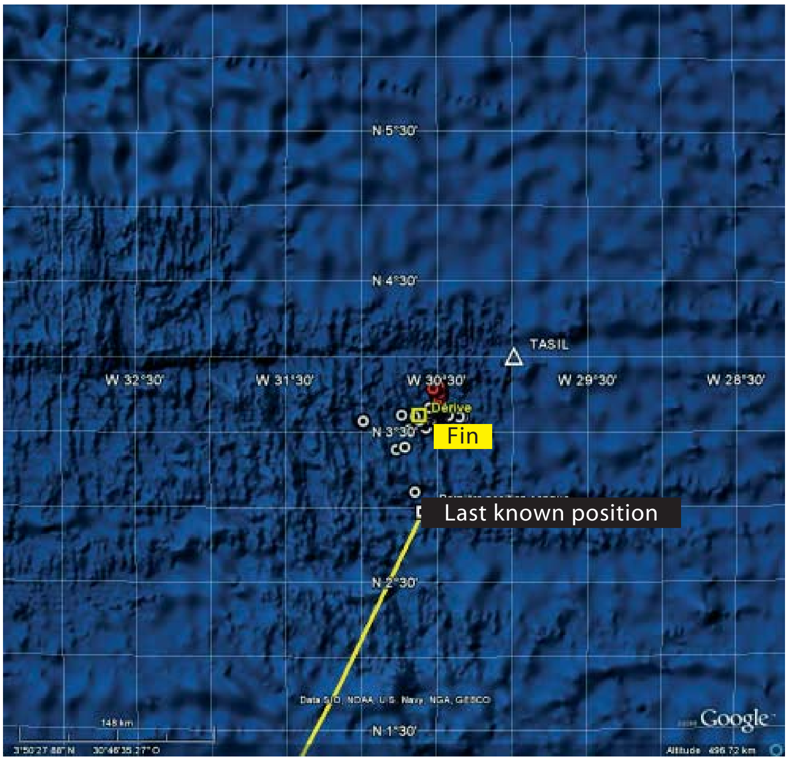
Appendix 4
Chronology of recovery of bodies and airplane parts

The document that follows summarises the chronology the recovery of the bodies and airplane parts between 6 June and 18 June 2009.

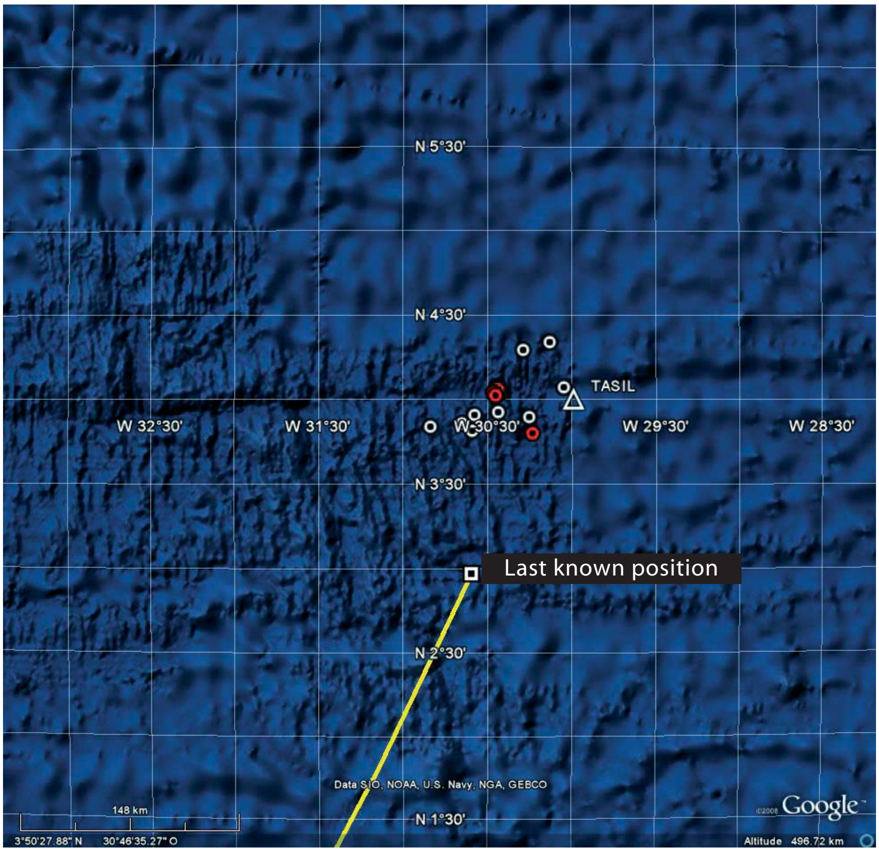
Note: the bodies are represented by a red circle and the wreckage with white circles.

Bodies and wreckage recovered on 6 June

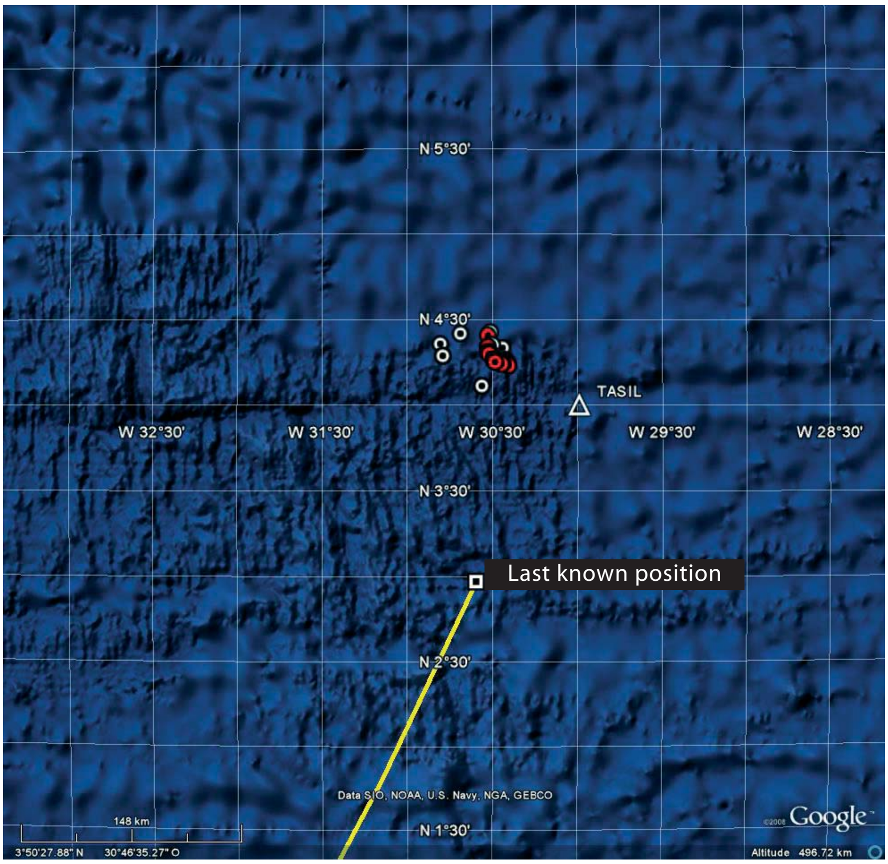
Bodies and wreckage recovered on 7 June (including the fin)



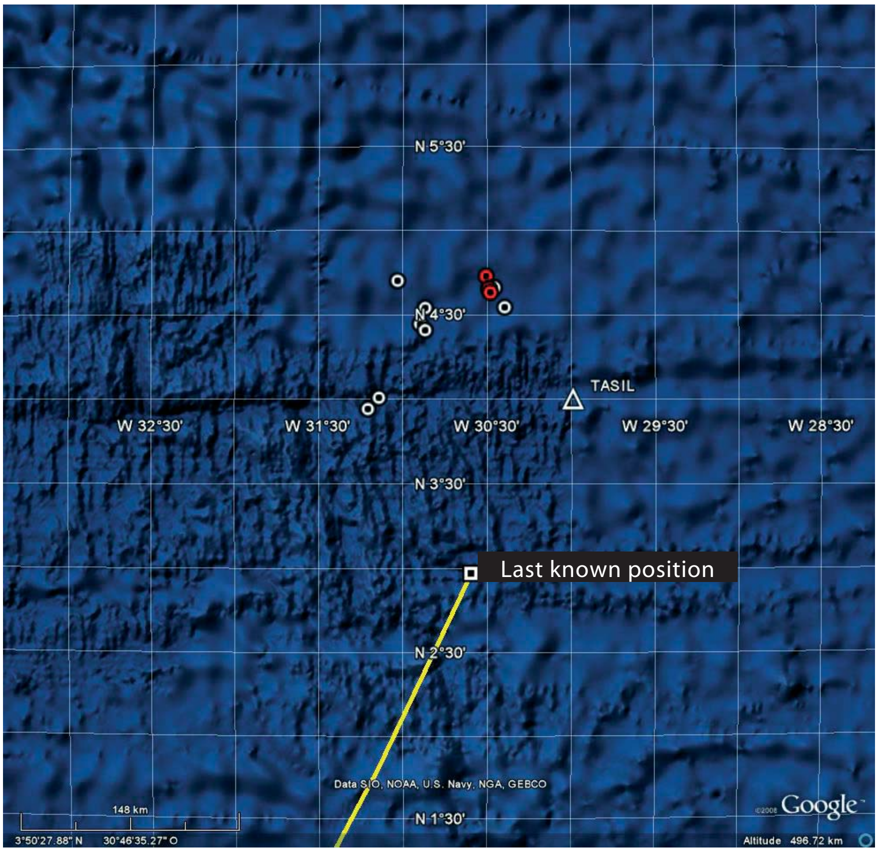
Bodies and wreckage recovered on 8 June



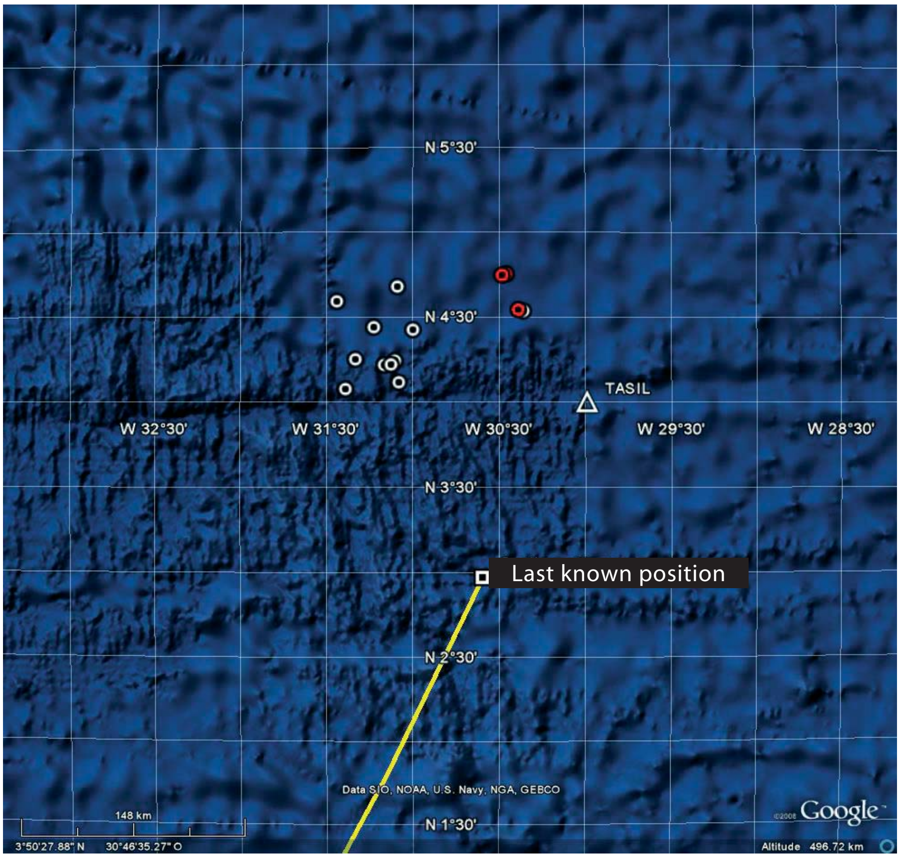
Bodies and wreckage recovered on 9 June



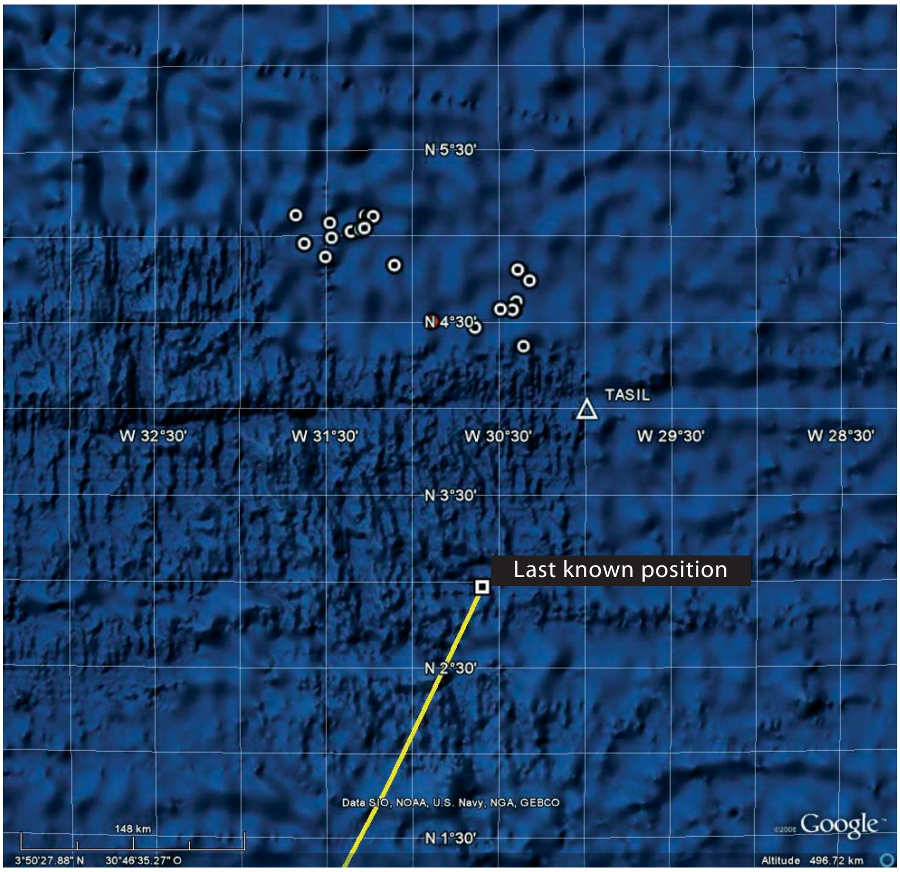
Bodies and wreckage recovered on 10 June



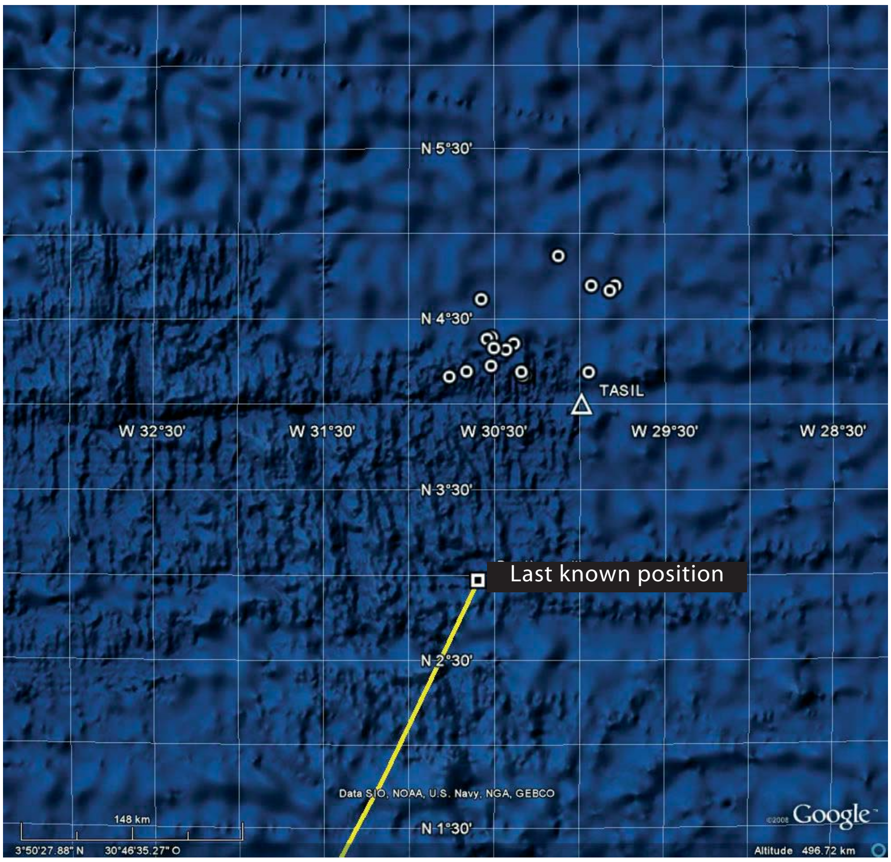
Bodies and wreckage recovered on 11 June



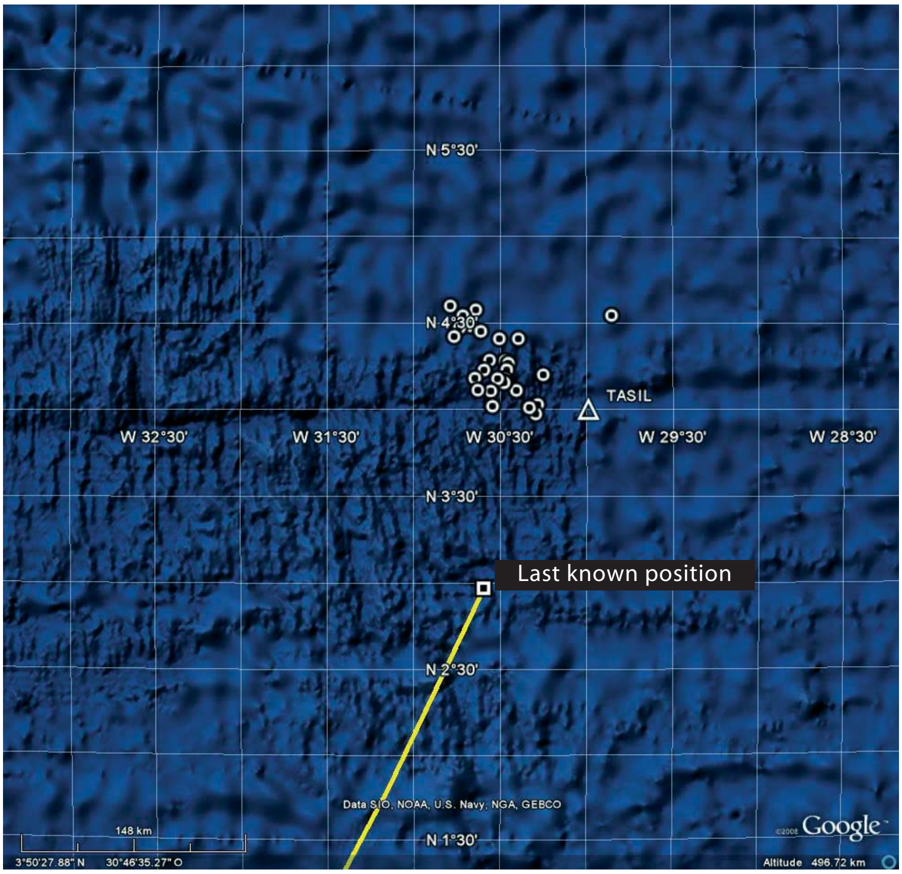
Bodies and wreckage recovered on 12 June



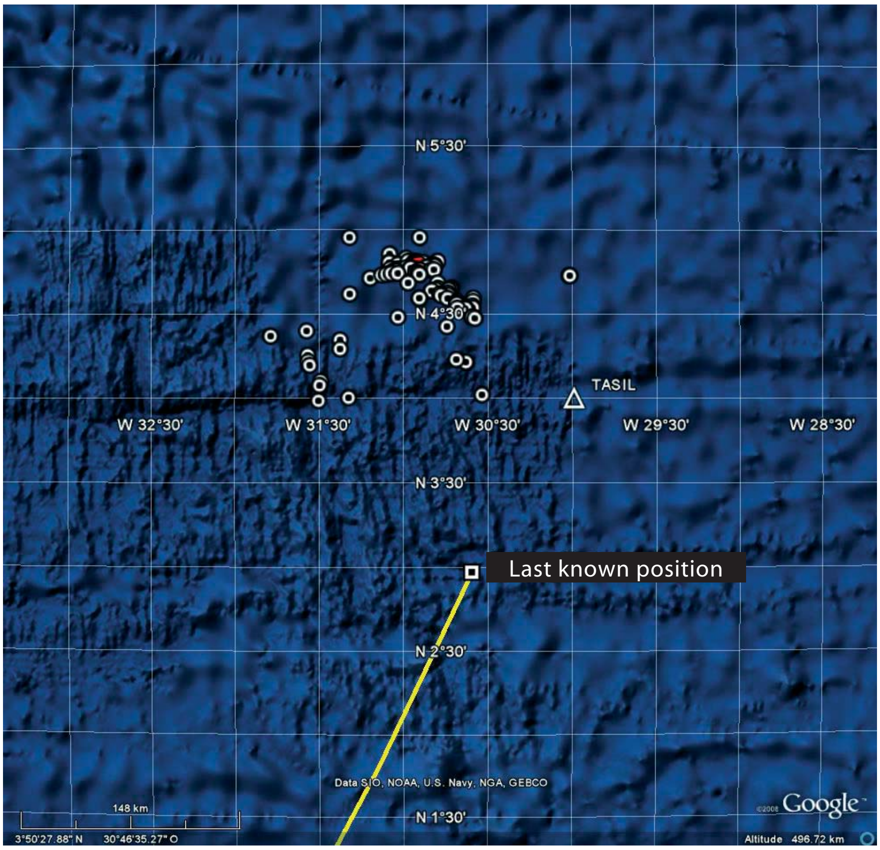
Bodies and wreckage recovered on 13 and 14 June



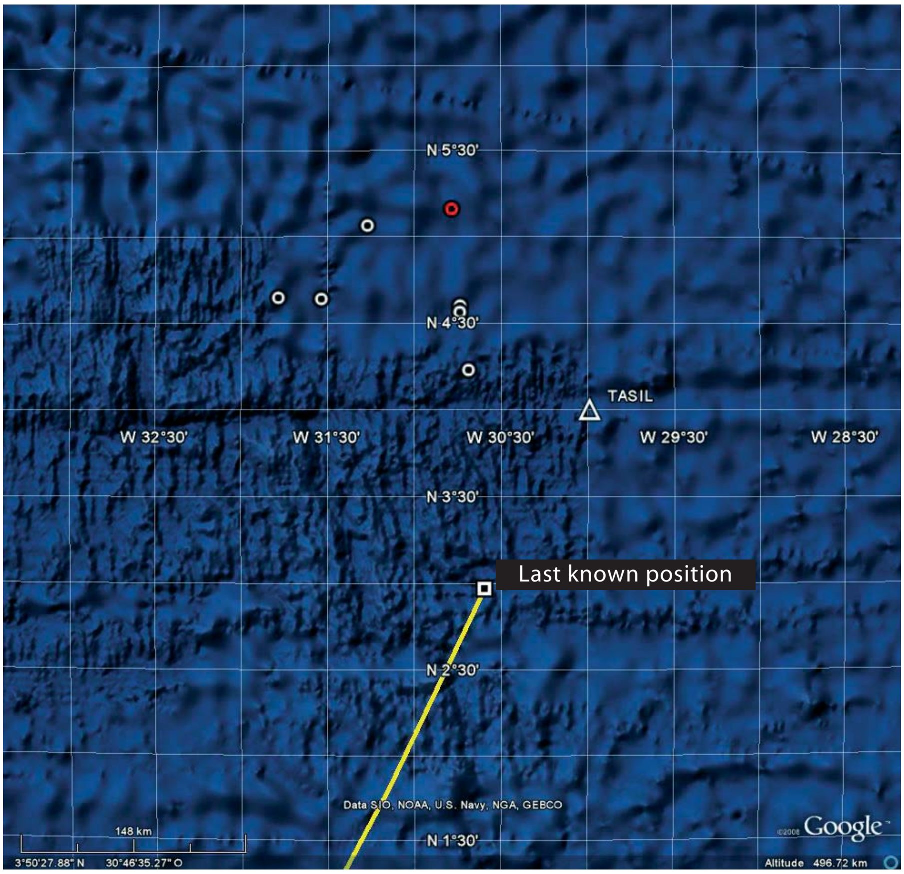
Bodies and wreckage recovered on 15 June



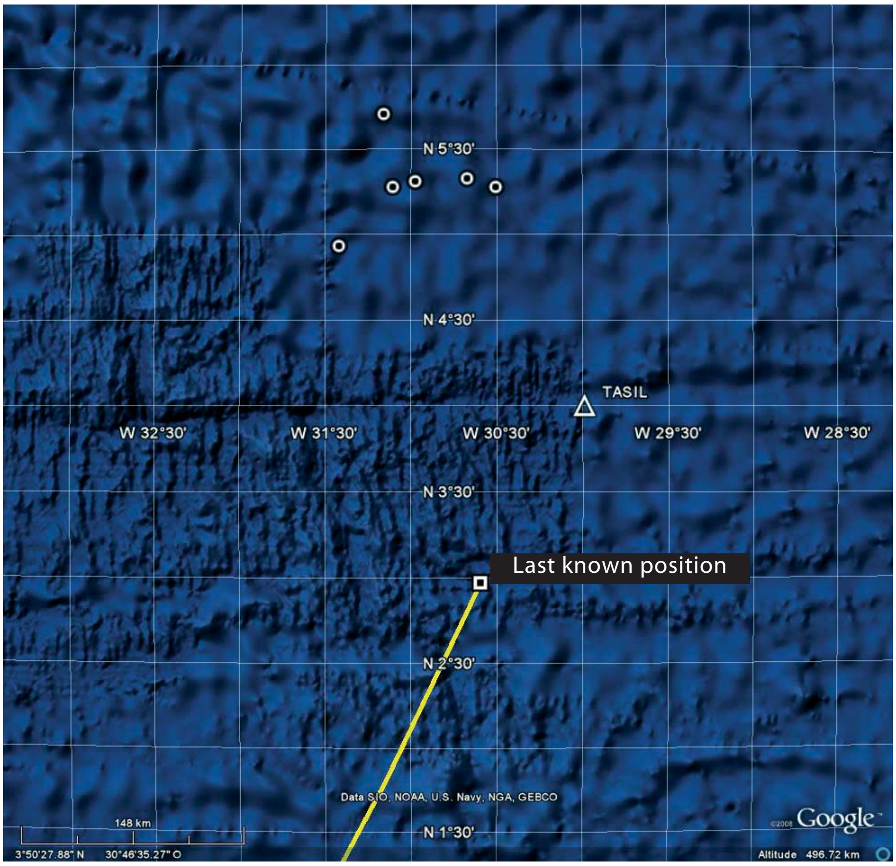
Bodies and wreckage recovered on 16 June



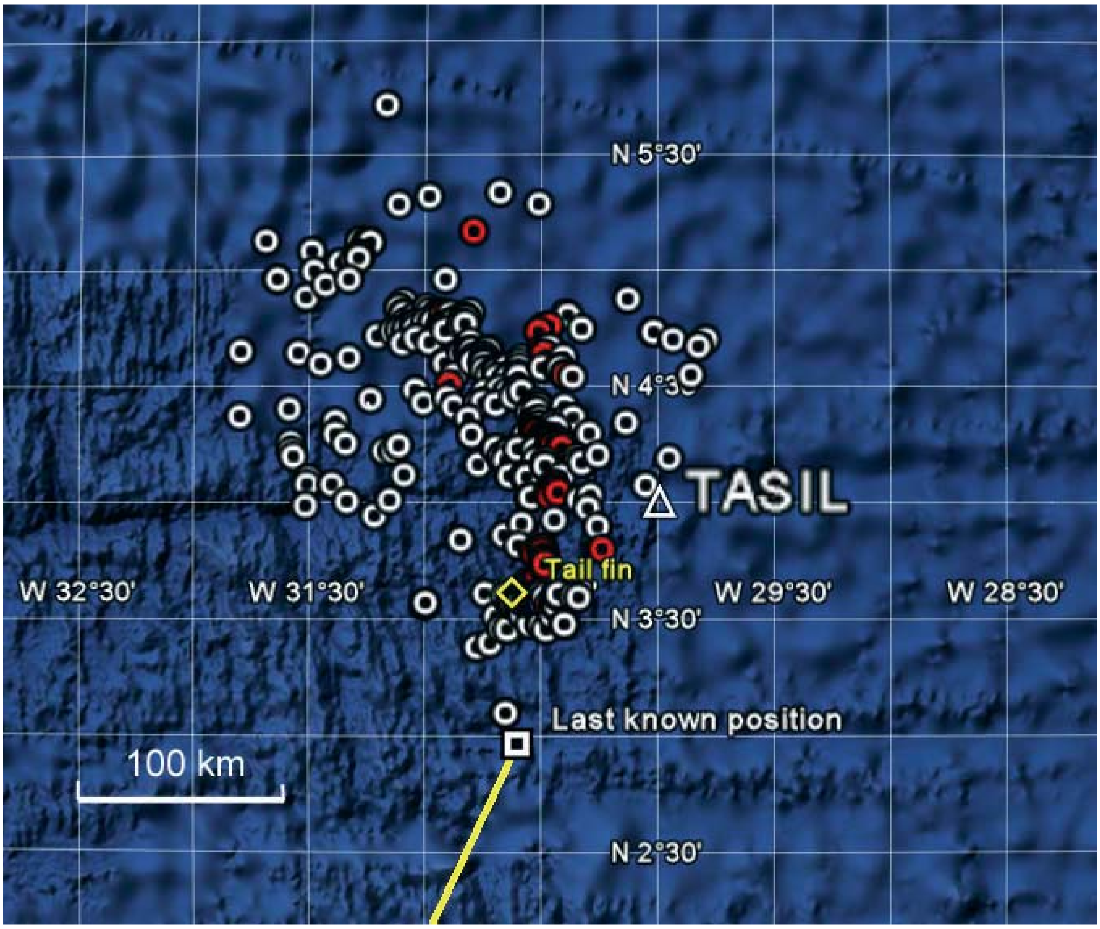
Bodies and wreckage recovered on 17 June



Bodies and wreckage recovered on 18 June



All of the bodies and wreckage recovered between 6 and 18 June



Appendix 5
Reference of procedures associated with some ECAM messages

Message ECAM mentionné dans le CFR	Procédure du Manuel d'Utilisation, Vol. 1 AF	Procédure du FCOM Vol. 3 Airbus	QRH AF	QRH AIRBUS	Procédures normales Systèmes AF	FCTM AIRBUS
AUTO FLT AP OFF	Procédure Anormale Urgence Secours (U/S) ECAM «Auto-flight AP OFF» 03-02-22-01	Abnormal and Emergency «Auto-flight AP OFF» 03-02-22 P2				
AUTO FLT REAC W/S DET FAULT	Procédure Anormale Urgence Secours (U/S) ECAM «Auto-flight REAC W/S DET FAULT» 03-02-22-06	Abnormal and Emergency «Auto-flight REAC W/S DET FAULT» 03-02-22 P3				
F/CTL ALTN LAW	Procédure Anormale Urgence Secours (U/S) ECAM «F/CTL ALTN LAW (PROT LOST)» 03-02-27-02	Abnormal and Emergency «F/CTL ALTN LAW (PROT LOST)» 03-02-27 P7				OP-020 ALTERNATE LAW (OPERATIONAL RECOMMENDATIONS)
FLAG ON CAPT PFD SPD LIMIT						
FLAG ON F/O PFD SPD LIMIT						
AUTO FLT A/THR OFF	Procédure Anormale Urgence Secours (U/S) ECAM «Auto-flight A/THR OFF» 03-02-22-02	Abnormal and Emergency «Auto-flight A/THR OFF» 03-02-22 P2				
NAV TCAS FAULT	Procédure Anormale Urgence Secours (U/S) ECAM «NAV TCAS FAULT» 03-02-34-15	Abnormal and Emergency «NAV TCAS FAULT» 03-02-34 P10	01.34.01: PAS D'ACTION PEQ			
FLAG ON CAPT PFD FD						

[1]The texts in italics and bold type refer to "memory items" or emergency manœuvres to perform from memory.

FLAG ON F/O PFD FD						
F/CTL RUD TRV LIM FAULT	Procédure Anormale Urgence Secours (U/S) ECAM «F/CTL RUD TRV LIM FAULT» 03-02-27-19	Abnormal and Emergency «F/CTL RUD TRV LIM FAULT» 03-02-27 P18				
FLAG ON CAPT PFD FPV						
FLAG ON F/O PFD FPV						
NAV ADR DISAGREE	Procédure Anormale Urgence Secours ECAM «F/CTL (NAV) ADR Disagree» 03-02-34-01 Renvoie à «NON ECAM ADR CHECK PROC» QRH 01.34.04 à 01.34.07 et TU 03-02-34-143 A 150	Abnormal and Emergency «NAV ADR DISAGREE» 3-02-34 P16 Renvoie à «ADR CHECK PROC» QRH 2.21 et FCOM 3-02-34 P17 A 22				
	«Vol avec IAS douteuse / ADR CHECK PROC» 03-02-34-143 A 150[1] Renvoie à «NON ECAM VOL EN ATMOSPHERE TURBULENTE» 02-03.30.01 à 03	***«Unreliable speed indic / ADR CHECK PROC» 3-02-34 P17 A 22***[1] Renvoie à «FCOM 3.04.91 SEVERE TURBULENCE»	01.34.04 à 01.34.07	2.21		AO-034 p 1 à 8: - UNRELIABLE SPEED INDICATION - ADR CHECK PROC / UNRELIABLE SPEED INDICATION
	«VOL EN ATMOSPHERE TURBULENTE» 02-03.30.01 à 03	FCOM 3.04.91 SEVERE TURBULENCE	03.10.01	5,01		ADVERSE WEATHER SI-010 TURBULENCE p 7 à 9 including «Use of radar»

	Technical Background : TU 02.02.34 P 11 à 15 RADAR METEO	Technical Background : FCOM 03.03.34 WEATHER RADAR			RADAR METEO MAC 02.02.04 P1 A 43	ADVERSE WEATHER SI-070 USE OF RADAR
F/CTL PRIM 1 FAULT	Procédure Anormale Urgence Secours ECAM «F/CTL PRIM 1 (2) (3) FAULT» 03.02.27.16 à 17	Abnormal and Emergency F/CTL PRIM 1 (2) (3) FAULT 3-02-27 P 6				
F/CTL SEC 1 FAULT	Procédure Anormale Urgence Secours ECAM «F/CTL SEC 1 (2) FAULT» 03.02.27.21	Abnormal and Emergency F/CTL SEC 1 (2) FAULT 3-02-27 P 7				
ADVISORY CABIN VERTICAL SPEED	TU 03.03.90.01 Procédures Anormales Complémentaires : ADVISORY	3.02.80 p 14 ECAM ADVISORY CONDITIONS	04.10.01	2.38		
Panne mentionnée en colonne «Fault» au CFR avec un cockpit effect ISIS SPEED OR MACH FUNCTION						

Appendix 6
ATC flight plan supplied by Air France

LFPGYEYX SBGLYOYX SBGLAFRK
(FPL-AFR447-IS
-A332/H-SPRIJWYG/SD
-SBGL2200
-N0481F350 DCT AWAKE UZ10 FLIRT/M082F350 UZ10 NTL UN873
INTOL/M082F350 UN873 SALPU/M082F370 UN873 ORARO/M082F370 UN873
ISOKA/N0471F370 UN873 LIMAL/N0466F390 UN873 SAMAR/N0468F380 UN873
BAROK/N0465F400 DCT PORTA UN873 MOKOR UN741 NTS/N0484F280 UN741
KEPER UT182 ROMLO/N0483F270 DCT
-LFPG1034 LFPO
-EET/SBBS0028 SBRE0050 SBAO0302 GOOO0349 GVSC0512 GCCC0606 LIMAL0643
GMMM0731 LPPC0816 LECM0851 LFRR0930 LFFF1004 RIF/ZMR UN976 DGO
UL176 SSN UP181 ENSAC SOLSO DIRAX LFBD REG/FGZCP SEL/CPHQ DAT/SV
DOF/090531)

Appendix 7
Study of route dossiers and associated fuel

The three flight plans proposed were:

(1) ETF M 0.82	load 38.6 t		TOF 68.4 t	TOW 233.0 t
(2) DCT M 0.82	load 37.5 t		TOF 69.5 t	TOW 233.0 t
(3) DCT M 0.81	with a planned load of 37.8 t		TOF 68.5 t	TOW 232.3 t

The route was identical on the three flight plans.

The ETF allowed the load to be increased by reducing the route reserve. The latter is calculated from a decision point up to the final destination. The route reserve thus went from 1,450 Kg to 360 Kg.

The flight level, the load reducing factor and the take-off weight (TOW) for flight plans 1 and 2 are identical. The difference in load is compensated by fuel. The navigation log (developed flight plan) was thus usable for flight plans 1 and 2.

The ATC flight plan in ETF was filed until the destination with (in box 18) a re-clearance in flight (RIF) including the decision point, the route and the optional technical stopover.

❒ Summary of the fuel quantities for the operational flight plans presented to the crew

Flight plan 1

```
ETF - CHO MAXI 38T6 - M.82 - ETOPS 120 - ETP 1-C-P NAT-SID /

    AFR    447/31   GIG /CDG    ETD 22.00   A330/ZCP    RC:5480  PLAN:0101
    ----------------------                  320.M82
               CARBUR  REEL    TEMPS  DIST  K 1.349     PREVU   LIMIT
    DEL CDG    063950  .....   10.34  5014  M.B.CORR.   126000
    DEG ORY    001900  .....   00.21  0083  CHARGE      038590
    R.RTE      000360  .....   00.03        ZFW         164590  170000
    RES FIN    002200  .....   00.30        TTL CARB    068910  109330
    CARBU SUP  000000  .....   00.00        TOW         233000  233000
    TR CARBU   000000  .....   00.00        DELEST      063950
    ROULAGE    000500  .....   00.20        LAW         169050  182000
    TTL CARB   068910  .....   11.28
```

Flight plan 2

```
DCT - M.82 - CHO MAXI 37T3 - ETOPS 120 - ETP 1-C-P NAT-SID /

    AFR    447/31   GIG /CDG    ETD 22.00   A330/ZCP    RC:5475  PLAN:0101
    ----------------------                  320.M82
               CARBUR  REEL    TEMPS  DIST  K 1.350     PREVU   LIMIT
    DEL CDG    063940  .....   10.34  5014  M.B.CORR.   126000
    DEG ORY    001900  .....   00.21  0083  CHARGE      037500
    R.RTE  3%  001460  .....   00.13        ZFW         163500  170000
    RES FIN    002200  .....   00.30        TTL CARB    070000  109330
    CARBU SUP  000000  .....   00.00        TOW         233000  233000
    TR CARBU   000000  .....   00.00        DELEST      063940
    ROULAGE    000500  .....   00.20        LAW         169060  182000
    TTL CARB   070000  .....   11.38
```

Flight plan 3

```
DCT - M.81 - ETOPS 120 - ETP 1-C-P NAT-SID /

    AFR   447/31  GIG /CDG   ETD 22.00  A330/ZCP   RC:5492 PLAN:0101
    ----------------------               310.M81
               CARBUR  REEL    TEMPS  DIST  K 1.363     PREVU   LIMIT
    DEL CDG    062940  .....   10.40  5014  M.B.CORR.   126000
    DEG ORY    001890  .....   00.21  0083  CHARGE      037800
    R.RTE  3%  001450  .....   00.15        ZFW         163800  170000
    RES FIN    002200  .....   00.30        TTL CARB    068980  109330
    CARBU SUP  000000  .....   00.00        TOW         232280  233000
    TR CARBU   000000  .....   00.00        DELEST      062940
    ROULAGE    000500  .....   00.20        LAW         169340  182000
    TTL CARB   068980  .....   11.46
```

❒ Summary of the fuel quantities for the final load sheet

A/C take-off weight	232757 Kg	
Block fuel	70900 Kg	
Estimated fuel at takeoff	70400 Kg	(500kg taxiing)

❒ Summary of the fuel quantities for the fuel fill order with explanations.

Fuel fill order		
Fuel supplied	81001 litres	
Density	0.789	
or	63909 Kg	
Fuel remaining arrival block	7400 Kg	idem ATL
or	71309 Kg	
Consumption APU	409 Kg (estimation by the crew consistent with APU consumption of 200 Kg/h with air bleed and electricity on during stopover)	
or	70900 Kg	
Estimation fuel for taxiing	500 K	
Estimated fuel at takeoff	70400 Kg	

Analysis of the load and of the quantity of takeoff fuel (TOF) confirms the possibility of a direct flight at M0.82, with a load reduction of 1.1 t and 0.9 t of additional fuel:

Note:

(1)	ETF M 0.82	load 38.6 t	TOF 68.4 t
(2)	DCT M 0.82	load 37.5 t	TOF 69.5 t
	-----------------	-----------------	---------------
	REAL	load 36.4 t	TOF 70.4 t

The minimum fuel required at start-up to undertake the flight without ETF at M 0.82 at a takeoff weight of 233 t was 70 t (69.5 t + 0.5 t for taxiing).

The operational fuel decided on by the captain was 70.9 t, in accordance with the operational flight plan approved by the latter.

Notes :

❒ Taxi fuel:

Set taxiing quantity, decided during flight preparation, of twenty minutes or 500 Kg, which is consistent with sequence from pushback and start-up to takeoff.

❒ Regulatory fuel:

The regulatory fuel necessary to perform a flight is determined at brake release before takeoff, thus 69.5 t in this case.

Appendix 8
Extract from Air France manual on fuel policy

5. CALCUL ET VERIFICATION DU CARBURANT

Le PNT doit vérifier le **carburant minimum requis** et le corriger si nécessaire. Le CDB décide ensuite du carburant opérationnel.

5.2. METHODE DE CALCUL

a) Déterminer le **carburant minimum requis** pour l'étape. Si OCTAVE est utilisé (cas général), les PNT actualisent ses éléments :

Délestage : masse (facteur k), QFU(s), niveau choisi / plan de vol ATC, phénomènes météorologiques, demande de température soute, tolérances techniques…

Dégagement : autre terrain, 2ème dégagement…

Roulage : dégivrage, LVP, fermeture piste…

ATTENTION ——————————————

Les Summary des plans de vol accélérés n'intègrent pas les éventuels carburants additionnels ou les contraintes de carburant critique ETOPS.
Si une telle contrainte affecte le plan de vol Octave principal et que le CDB décide d'utiliser un profil de vol accéléré, il doit demander au DISPATCH l'édition d'un plan de vol OCTAVE accéléré ***développé*** *qui présentera les nouvelles quantités réglementaires.*

——————————————

b) Déterminer, si nécessaire, le carburant maximum résultant de la limitation opérationnelle du jour.

c) Déterminer le carburant qui correspond au plus près à ses besoins pour l'étape, en additionnant :

- la quantité carburant souhaitée à l'arrivée à l'aérodrome de destination,
- la quantité correspondant au transport carburant à titre opérationnel ou économique,
- le délestage d'étape actualisé des quantités correspondant à la stratégie retenue pour le vol,
- le roulage.

Au vu de ces éléments et des valeurs associées aux couvertures statistiques 90% ou 99%, le CDB décide de la quantité de carburant au départ.

Rappel : dans le cadre de la procédure plein partiel, le carburant calculé au stade de la préparation des vols sera reconsidéré à H-30.

Appendix 9
Procedure for flight with unreliable IAS / ADR check

A330/340	**Procédures anormales**	TU **03.02.34. 143**
AIR FRANCE	**URGENCE / SECOURS**	28 SEP 06
OA.NT	**ATA 34 - NAVIGATION**	***A330***

VOL AVEC IAS DOUTEUSE / ADR CHECK PROC *(A330)*

Une indication erronée de la vitesse peut être la conséquence de l'endommagement du radome ou d'un défaut de sonde pitot ou de prise statique (panne réchauffage, obstruction, déformation etc...).
Si les prises de pression statique sont affectées, l'altitude affichée peut être erronée.
Des indications anémométriques erronées ne peuvent pas être détectées par les ADIRU.
Les calculateurs des commandes de vol et de guidage (FG) rejettent normalement les ADR fournissant des vitesse / altitude erronées, à condition qu'un écart significatif soit détecté.
Toutefois, ils ne seront pas capables de rejeter deux altitudes ou vitesses erronées qui dérivent parallèlement et d'une même grandeur. Dans ce cas exceptionnel, les systèmes avion considèreront la source correcte comme étant fausse, et la rejetteront. Les calculateurs des commandes de vol et de guidage utiliseront les deux ADR incorrectes pour leurs calculs.
Par conséquent, dans toutes les situations d'indications anémomètriques erronées, l'équipage doit identifier la (ou les) ADR en défaut, et la (ou les) sélecter sur OFF (selon la procédure ADR CHECK PROC). Si toutes les ADR donnent des informations erronées, garder une ADR sur ON pour conserver la protection Stall Warning. Pendant la durée de l'identification de la panne, les lois de commandes de vol pouvant être affectées, il est recommandé de manoeuvrer l'avion avec précaution jusqu'à ce que les ADR soient sélectées sur OFF.

- **Les informations de vitesse ou d'altitude erronées**, qui peuvent être mises en évidence par :
  . a la suite d'une alarme ECAM F/CTL ADR DISAGREE, s'il y a un écart de vitesse (>16kt) entre les 2 ADR restantes
  . des écarts de vitesse entre les ADR 1, 2, 3 et l'anémomètre de secours, ou
  . des indications de vitesse ou d'altitude gelées, fluctuantes, croissant / décroissant inopinément, ou
  . une corrélation anormale des paramètres de vol basiques (vitesse, assiette, poussée, taux de montée), ou
  . un comportement anormal des AP / FD / ATHR, ou
  . une incohérence entre la hauteur radio sonde et l'altitude baromètrique, ou
  . une réduction du bruit aérodynamique avec une vitesse qui augmente, ou un accroissement du bruit aérodynamique avec une vitesse qui diminue, ou
  . l'impossibilité de sortir les trains d'atterrissage par la commande normale des trains, ou
  . une alarme STALL ou OVERSPEED, ou un message ECAM Flap RELIEF en contradiction avec au moins une des vitesses indiquées; dans ce cas :
    - tenir compte de l'alarme décrochage qui peut être déclenchée en loi alternate ou directe. Fonction de l'angle d'incidence; cette alarme n'est pas affectée par des indications anémométriques erronées.

- selon la panne, l'alarme OVERSPEED peut être fausse ou avérée. Le BUFFETING, associé à l'alarme OVERSPEED VFE, est un symptôme de survitesse réelle.

Règles d'application de la procédure :

- **Si les informations erronées de vitesse ou d'altitude n'affectent pas la sécurité du vol** (trajectoire stabilisée), identifier la ou les ADR en défaut et la mettre sur OFF. Pour cela il est nécessaire de comparer les vitesses avec celles des tableaux de vitesse ou vol en turbulence.

- **Si la sécurité du vol est affectée** (toutes les indications de vitesse sont erronées, ou si l'indication de vitesse fausse ne peut être clairement identifiée), sélecter deux ADR sur OFF pour éviter que les lois de commandes de vol reçoivent des informations erronées des indications anémométrique et **appliquer la procédure suivante.**
  . Appliquer les actions immédiates (équivalent de la manoeuvre d'urgence) : AP/FD/ATHR OFF, poussée et attitude,
  . Une fois stabilisé, en fonction de la phase de vol, afficher une poussée et une assiette et déterminer la ou les ADR en défaut.
  . Si la ou les ADR en défaut ne peuvent être identifiées, sélecter deux ADR sur OFF

ATTENTION

En cas de détérioration du radome, la traînée sera augmentée et par conséquent le N1 sera augmenté de 3 % (CRZ) ou 1,5 % (APP). Le FF augmentera d'environ 13 %.

Effectuer les actions immédiates suivantes (Manoeuvre d'urgence):

- **AP / FD . . . . OFF**
- **A/THR . . . . OFF**
- **POUSSEE / ASSIETTE . . . . SELECTEES**

➤ Si la panne survient avant la réduction de poussée :

- **POUSSEE / ASSIETTE . . . . TOGA / 15°**

➤ Si la panne survient après la réduction de poussée :

- Au dessous du FL 100
  - **POUSSEE / ASSIETTE . . . . CLB / 10°**
- Au dessus du FL 100
  - **POUSSEE / ASSIETTE . . . . CLB / 5°**

- **VOLETS . . . . CONFIG MAINTENUE**
- **SPEED BRAKES . . . . VERIFIES RENTRES**
- **TRAIN . . . . RENTRE**

A l'altitude de sécurité ou d'attente effectuer un palier.

- **ALTITUDE GPS . . . . AFFICHEE AU MCDU**
- **ATTITUDE / POUSSEE . . . . AJUSTEES**

Ajuster l'assiette et la poussée en fonction du tableau ci-après.

⇩

POUSSEE / ASSIETTE pour le FL d'attente

BECS / VOLETS SORTIS				
		Au dessous de 160t	160t à 190t	Au dessus de 190t
CONF	VITESSE	ASSIETTE (°) / POUSSEE (% N1)		
3	F	7 / 64.3	7.5 / 70.7	7.5 / 76.3
2	F	8.5 / 62.4	9 / 69.2	9 / 75
1 + F	S	6 / 60.5	6 / 66.9	6 / 72.7
1	S	9 / 59.5	9 / 65.7	9 / 71.6

CONFIGURATION LISSE				
FL	VITESSE	ASSIETTE (°) / POUSSEE (% N1)		
Au dessous FL 250	240 kt	2.5 / 68.1	4 / 72.6	5 / 75.7
FL 250 à FL 370	260 kt	2 / 83.9	3 / 87.9	3.5 / 90.0
Au dessus FL 370	M 0.80	2 / 90.0	2.5 / 93.4	3 / 94.3

LORSQUE LA TRAJECTOIRE EST STABILISEE

- **PROBE / WINDOW HEAT . . . . ON**

Recommandations :

- Respecter l'alarme STALL et ignorer le message STATUS "RISK OF UNDUE STALL WARNING" affiché à l'ECAM.
- Pour contrôler la vitesse se référer à la vitesse sol des IRS ou des GPS

Si les indications d'altitude sont affectées.

- Ne pas utiliser le FPV et/ou la V/S, ils ne sont pas fiables.
- L'altitude transmise par le transpondeur à l'ATC n'est pas fiable, informer le contrôle aérien.
- Utiliser l'altitude GPS sur la page GPS Monitor du MCDU : les variations d'altitude peuvent être utilisées pour le contrôle de l'altitude de vol. Cette indication est indépendante de toutes informations anémométriques.
- Utiliser la hauteur radio sonde.

⇩

ATTENTION ——————————————————————————————

En cas de détérioration du radome, la traînée sera augmentée et par conséquent le N1 sera augmenté de 3 % (CRZ) ou 1,5 % (APP).
Le FF augmentera d'environ 13 %.

——————————————————————————————————

- **ADR EN DEFAUT. . . . . DETERMINEE(S)**

  Comparer toutes les indications de vitesse avec celles des tableaux du QRH :
  - *. **VITESSES** d'utilisation pour les vitesses F ou S (QRH 02.01.XX).*
  - *. **VOL EN TURBULENCE** pour les vitesses en configuration lisse (QRH 03.10.01).*

➤ Si les informations d'au moins une ADR sont fiables :

- **ADR EN DEFAUT . . . . OFF**
- **ADR RESTANTE (S). . . . . VERIFIEE(S)**

  Vérifier les autres sources pour valider l'ADR restante:
  - *GPS : altitude*
  - *GPS et IRS : vitesse sol (prenant en compte l'altitude et les effets du vent),*

➤ Si les ADR en défaut ne peuvent être identifiées ou si toutes les ADR sont en défaut :

- **UNE ADR . . . . LAISSEE SUR ON**

  Conserver une ADR sur ON, pour garder la protection Stall Warning.
- **DEUX ADR . . . . OFF**

  Cela évite que les lois de commandes de vol soient affectées en utilisant deux sources cohérentes mais non fiable provenant des ADRs.

- **EFIS DMC SWITCHING . . . . COMME NECESSAIRE**

⇩

- Retour vers l'aéroport de décollage :

  Il est préférable de garder la configuration de décollage.

  Se référer aux tableaux ci-après pour Approches initiale et intermédiaire et Approche finale.

- Après décollage, si le vol est poursuivi :

  Monter à l'altitude de sécurité ou à l'altitude du circuit d'attente

  - POUSSEE. . . . . CLB

  - VOLETS . . . . RENTRES

  Une fois la poussée CLB affichée, rentrer les volets de la position 3 ou 2 vers 1.
  Lorsque l'assiette est inférieure à l'assiette de la vitesse S (Cf tableau - POUSSEE / ASSIETTE pour le FL d'attente ci-dessus) les volets peuvent être rentrés de la position 1 à 0.
  Une fois en configuration lisse, se référer aux tableaux ci-après pour la montée, croisière, descente et l'approche.

- Autres cas :

  Se référer aux tableaux ci-après pour la montée, croisière, descente et l'approche.

MONTEE

- Afficher la poussée CLB.

CONFIGURATION LISSE				
		< à 160t	160 t à 190 t	> à 190 t
FL	VITESSE	ASSIETTE (°) / POUSSEE (% N1)		
< au FL 100	240 kt	12.5 / CLB	11 / CLB	10.5 / CLB
FL 100 - FL 150		10.5 / CLB	9.5 / CLB	9 / CLB
FL 150 - FL 200		10.5 / CLB	8.5 / CLB	8.5 / CLB
FL 200 - FL 250		7.5 / CLB	7.5 / CLB	7.5 / CLB
FL 250 - FL 300	260 kt	5.5 / CLB	5 / CLB	5.5 / CLB
FL 300 - FL 370		4 / CLB	4 / CLB	4.5 / CLB
> au FL 370	M 0.80	3.5 / CLB	3.5 / CLB	3.5 / CLB

CROISIERE

- Ajuster le N1 de manière à maintenir un niveau de vol avec une assiette constante. Lorsque le temps le permet, se reporter au tableau "VOL EN TURBULENCE " (QRH) et ajuster l'assiette pour maintenir le niveau de vol.

CONFIGURATION LISSE				
		< à 160t	160 t à 190 t	> à 190 t
FL	VITESSE	ASSIETTE (°) / POUSSEE (% N1)		
< au FL 250	240 kt	2.5 / 68.1	4 / 72.6	5 / 75.7
FL 250 - FL 370	260 kt	2 / 83.9	3 / 87.9	3.5 / 90.0
> au FL 370	M 0.80	2 / 90.0	2.5 / 93.4	3 / 94.3

DESCENTE

- Afficher la poussée IDLE

CONFIGURATION LISSE				
		< à 160t	160 t à 190 t	> à 190 t
FL	VITESSE	ASSIETTE (°) / POUSSEE (% N1)		
> au FL 370	M 0.80	- 0.5 / IDLE	0 / IDLE	1 / IDLE
FL 370 - FL 250	260 kt	- 1 / IDLE	0.5 / IDLE	1.5 / IDLE
FL 250 - FL 100	240 kt	- 0.5 / IDLE	0.5 / IDLE	2 / IDLE
< au FL 100	240 kt	- 0.5 / IDLE	0.5 / IDLE	2.5 / IDLE
< au FL 100	G - DOT	2.5 / IDLE	2.5 / IDLE	2.5 / IDLE

APPROCHES INITIALE ET INTERMEDIAIRE EN PALIER

- La phase d'approche entre Green Dot et la configuration finale (CONF 3) est effectuée en palier.

EN PALIER TRAIN RENTRE				
		< à 160t	160 t à 190 t	> à 190 t
CONF	VITESSE	ASSIETTE (°) / POUSSEE (% N1)		
0	G-DOT	5 / 55.3	5.5 / 61.5	5 / 67.4
1	S	9 / 59.5	9 / 65.8	9 / 71.7
1 + F (a)	S	6 / 60.5	6 / 66.9	6 / 72.7
2	F	6 / 64.0	6 / 69.2	6 / 75.0
EN PALIER TRAIN SORTI (b)				
3	F	6.5 / 69.1	6.5 / 75.4	6.5 / 81.5

(a) Etant donné que la vitesse est incertaine, le SFCC peut sélecter la CONF 1 + F au lieu de la CONF 1
(b) Si la vitesse fournie par les ADR est supérieur à 280kts, il sera nécessaire d'effectuer une sortie du train par gravité.

APPROCHE FINALE SELON UNE PENTE DE - 3°

TRAIN SORTI				
		< à 160t	160 t à 190 t	> à 190 t
CONF	VITESSE	ASSIETTE (°) / POUSSEE (% N1)		
3	VLS + 10	4 / 48.2	4 / 53.2	4.5 / 59.0

ATTERRISSAGE

- DISTANCE D'ATTERRISSAGE . . . . DETERMINEE
Se reporter au tableau de corrections après panne DOUBLE ADR FAULT Cf TU 03.02.90.1xx ou QRH.

❍

BEA

Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

Zone Sud - Bâtiment 153
200 rue de Paris
Aéroport du Bourget
93352 Le Bourget Cedex - France
T : +33 1 49 92 72 00 - F : +33 1 49 92 72 03
www.bea.aero

N° ISBN : 978-2-11-098704-4