PHD COURSE IN LIFE AND ENVIRONMENTAL SCIENCES

Report Form for PhD student annual evaluation (XXXVII and XXXVIII cycles)

Name of PhD student: Paolo GARBATI

Title of PhD research: Analysis of Climate Change Impact on the Aviation and Safety Strategies in the European Airports.

Name of PhD supervisor: Prof. Fausto MARINCIONI
Research lab name: DLAB – Disaster Risk Reduction Laboratory

Cycle:
[ ] XXXVII
[**X**] XXXVIII

PhD Curriculum:
[ ] Marine biology and ecology
[ ] Biomolecular Sciences
[**X**] Civil and environmental protection

DISVA instrumentation labs/infrastructure eventually involved in the project:
[ ] Actea Mobile Laboratory
[ ] Advanced Instrumentation lab
[ ] Aquarium
[ ] MassSpec lab
[ ] MaSBiC
[ ] Simulation/informatics lab
[ ] Other. Please, indicate: ....

ABSTRACT (1000 characters, including spaces):
In the first year of the PhD program, the focus was on literature research, courses, and webinars to understand the subject comprehensively and create a structured framework. This led to a better understanding of global climate change impacts and regulatory obligations on airports. Additionally, historical windstorm influences on flight incidents and the role of the Aircraft Commander in aviation safety were explored. Despite advanced technology, crew intuition and experience remain crucial. Future steps involve deeper insight into weather forecasting technologies, collaboration with Italian multinational corporation *Leonardo spa*, and data collection through surveys and interviews with aviation safety stakeholders. The final phase includes gathering information, comparing 'Single European Sky Air Traffic Management Research (SESAR)' with 'Next Generation Air Transportation System (NextGen)' to suggest procedural strategies for preventing aviation disasters, especially at European airports without advanced meteorological technologies.

Part 1. Scientific case of the PhD Research (2 to 3 pages, including figures)

- BACKGROUND

The periodic reports from the Intergovernmental Panel on Climate Change (IPCC) emphasize the growing impact of climate change and the increasing occurrence of severe weather events. This study focuses on understanding how these phenomena affect aviation safety, with a particular focus on windstorms, a critical factor in aviation. When the wind becomes excessive or unpredictably variable, it can shift from being a navigational aid to a potential threat, including microbursts and wind shear.

During the first year of research, we reviewed literature, visited official data sources of international and national organizations, researched aviation regulations and standards, and traced technological advancements since the 1970s. During this period, the causes of many incidents during takeoff and landing were unclear, though sudden gusts of wind were suspected. Pioneering scientists like Tetsuya T. Fujita and James W. Wilson identified microbursts and low-level wind shear (below 2000 ft altitude), leading to the development of advanced technologies such as Terminal Doppler Weather Radar (TDWR), Low-Level Wind Shear Alert System (LLWAS), Light Detection And Ranging (LIDAR), Sonic/Sound Detection And Ranging (SODAR), and avionics systems.

These devices provide timely warnings to pilots, enabling them to apply specialized training and prevent accidents. However, airport meteorological forecasting facilities face limitations, including high costs and geographical challenges. It's important to recognize that technology complements human expertise. From meteorologists to aircraft commanders and air traffic controllers, all play essential roles in ensuring flight safety, drawing on their experience, training, and skills.

In conclusion, this research aims to offer recommendations to help even airports without advanced technologies address severe meteorological phenomena. This includes adjusting safety procedures to maintain high flight safety standards and minimize economic losses.

- SCIENTIFIC AIMS

The research aims to analyse data on significant atmospheric phenomena that have impacted air traffic in Europe, and to consider potential strategies to mitigate the risk of aviation disasters.

- WORKPLAN AND RESEARCH ACTIVITIES

WP 1. Objective. To assess the actual state of global climate change, with a particular focus on Europe but not limited to it, in order to better understand the severity and frequency of intense weather events that could impact flight safety in the near future. To deepen knowledge about the technological devices used for microburst prediction and ground and onboard wind shear detection. To gain an expanded perspective on managing a large-scale emergency, enabling the identification of priority actions to optimize rescue efforts, which may be considered in the development of airport emergency procedures.

Methods. Much of the work was conducted by reviewing numerous scientific studies, exploring government organization data repository, and comparing regulatory sources in the aviation sector between the United States (where intense meteorological phenomena are more common and well-studied) and Europe, including Italy. Information was also gathered on the number and severity of flight incidents (Tab. 1) due to wind (as the primary cause or contributing factor), the occurrences of wind shear in Italian airports (Tab. 2) over a 10-year period (2007-2017), as well as ground technologies (Doppler Radar, anemometer rings, other sonic or optical equipment) and onboard avionics systems in commercial aircraft. Concerning the acquisition of information regarding the management of a large-scale emergency, a 48-hour internship was completed by participating in an exercise organized within the framework of the European Civil Protection Mechanism in June 2023.

ACCIDENT AND INCIDENT FOR WIND SHEAR, TURBOLENCE AND MICROBURST (1956-2020)

	DATE	LOCATION	AIRCRAFT/Flight Number	Phase of Flight	Occupant Fatalities/injured	Aircraft Damage	Note	Source
1	24th June 1956	Kano, Nigeria	BOAC 252/773	Take off	32 fatalities - 11 injured	Hull loss		*
2	30th January 1974	Pago Pago, Samoa (USA)	Pam Am 806	Landing	96 fatalities - 4 injured	Hull loss		*
3	07th August 1975	Denver, Colorado (USA)	Cont 426	Landing	15 injured	Hull loss		*
4	24th June1975	JFK New York (USA)	Eastern 66	Landing	112 fatalities - 12 injured	Hull loss	Microburst	*
5	23rd June 1976	Philadelphia, Pennsylvania (USA)	Allegery 121	Landing	86 injured	Hull loss		*
6	03rd June 1977	Tucson, Arizona (USA)	CONT 63	Take off	N0/No	Major		*
7	14 March 1979	Doha, Qatar	Royal Jordan 600	Landing	45 fatalities - 15 injured	Hull loss		*
8	22nd August 1979	Atlanta, Georgia (USA)	Eastern 693 Boeing 727-125	Landing	N0/No	No	near crash	*
9	09th july 1982	New Orleans, Louisiana (USA)	Pan Am 759	Take off	152 fatalities	Hull loss	Microburst	*
10	13rd June 1984	Detroit, Michigan (USA)	US Air 183	Take off	N0/No	Major		*
11	02nd August 1985	Dallas, Texas (USA)	Delta 191	Landing	134 fatalities	Hull loss	Microburst	*
12	3rd September 1989	Santiago, Cuba	IL 62	Take off	169 fatalities	Hull loss	Microburst	*
13	21st December 1992	Faro, Porugal	MartinAir 495	Landing	56 fatalities - 106 injured	Hull loss		*
14	2nd July 1994	vicinity Charlotte NC USA_	McDonnell Douglas DC93	Landing	37 fatalities	Hull loss		**
15	1st June 1999	Little Rock USA	McDonnell Douglas MD82	Landing	11 fatalities	Hull loss		**
16	3rd December 1999	vicinity Billund Denmark	Boeing 737-500 (B735)	Landing	No/No	No		**
17	18th January 2001	Brisbane Australia	Boeing 737-400 (B734)	Go around	No/No	No	Microburst	**
18	7th February 2001	Bilbao Spain	Airbus A320	Landing	25/143 injured	Major		**
19	21st January 2002	Hakodate Japan	Airbus A321	Landing	No/No	Major		**
20	28th February 2002	en-route North Sea UK	AEROSPATIALE AS-332 Super Puma (Helicopter)	Cruise	No/No	Minor		**
21	10th December 2005	vicinity Port Harcourt Nigeria	McDonnell Douglas DC93	Go around	108 fatalities	Hull loss		**
22	23rd September 2005	en-route Hawaii USA	AEROSPATIALE AS-350 (Helicopter)	Cruise	3 fatalities	Hull loss		**
23	1st September 2005	Squaw Lake Quebec Canada	De Havilland Canada DHC-2 Beaver	Cruise	All occupants fatalities	Hull loss		**
24	29th October 2006	vicinity Abuja Nigeria	Boeing 737-200 (B732)	Take off	96/105 fatalities - 9 injured	Hull loss		**
25	15th April 2007	Sydney Australia	Boeing 747-400 (B744)	Landing	No/No	minor	Hard landing	**
26	20th December 2008	Denver USA	Boeing 737-500 (B735)	Take off	6/115 seriously injured 41 minor	Hull loss		**
27	14th September 2010	vicinity Wuxi China	Airbus A319	Cruise	No/No	No	Loss of contro	**
28	02nd December 2010	vicinity Svolvaer Norway	DE HAVILLAND CANADA Dash 8 Q100 (DH8A)	Landing	No/No	No	Microburst	**
29	04th April 2011	Kinshasa Democratic Republic of Co	BOMBARDIER Regional Jet CRJ-100 (CRJ1)	Go around	33/34 fatalities - 1 seriously injure	Hull loss		**
30	23rd December 2011	Manchester UK	Airbus A321-200	Landing	No/No	Minor		**
31	20th April 2012	vicinity Islamabad Pakistan	Boeing 737-200 (B732)	Landing	All occupants fatalities (127)	Hull loss		**
32	19th November 2012	vicinity Milan, Italy	Boeing 767	Cruise	Some injured	No	Turbolence	***
33	25th October 2013	San Sebastian Spain	BOMBARDIER Regional Jet CRJ900 (CRJ9)	Landing	No/No	Major	Hard landing	**
34	07th October 2014	Montréal QC Canada	Airbus A330-300 (A333)	Landing	No/No	No		**
35	02nd January 2014	vicinity Cork Ireland	ATR-72-500 (AT75)	Landing	No/No	No	n.2 go around	**
36	15th August 2015	Charlotte NC USA	Airbus A321	Landing	No/No	Major		**
37	02nd February 2015	Rhodes Greece	British Aerospace Jetstream 41 (JS41)	Landing	No/No	Major		**
38	19th August 2017	Bogotà Colombia	Airbus 340-300 (A343)	Take off	No/No	No		**
39	27th October 2017	vicinity Salzburg Austria	Embraer E-195	Go around	No/No	No		**
40	06th December 2018	Burbank CA USA	Boeing 737-700	Landing	No/No	Minor		**
41	04th August 2018	en-route west of Chur Switzerland	Junkers Ju 52/3m (JU52)	Landing	20 fatalities	Hull loss		**
42	01st September 2018	Sochi Russia	Boeing 737-800	Landing	No/No	Major		**
43	27th May 2018	vicinity Madrid Barajas Spain	n. 2 A320 / n.2 CRJX / n.3 B738 / n.1 A332	Go around/Misse	No/No	No	Risk of collisio	**
44	20th February 2018	Port Harcourt Nigeria	McDonnell Douglas MD83	Landing	No/No	Major		**
45	28th August 2018	Macau SAR China	Airbus A320	Landing	Few occupants injuries	Major		**
46	05th May 2019	Moscow Sheremetyevo Russia	SUKHOI Superjet 100-95 (SU95)	Landing	41/73 fatalities - 3 serious injured	Hull loss		**
47	09th February 2020	East Midlands UK	Boeing 737-800	Take off	No/No	Minor		**

* https://ral.ucar.edu/solutions/products/low-level-wind-shear-alert-system-llwas - 24/04/2023

** https://skybrary.aero/articles/low-level-wind-shear - 24/04/2023

*** Agenzia Nazionale per la Sicurezza del Volo

Table 1

NUMBER OF WIND SHEAR PER YEAR IN THE ITALIAN AIRPORTS

Airport	Cod. ICAO	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	TOTALE
Bari Palese	LIBD	21	30	18	19	18	18	15	32	39	12	34	256
Pescara	LIBP	11	10	12	11	4	6	1	3	8	3	18	87
Lamezia Terme	LICA	17	19		11	11	12	3	12	15	20	4	124
Catania Fontanarossa	LICC	10	10	21	14	18	51	6	75	111	220	125	661
Palermo Punta Raisi	LICJ	209	214	258	228	138	93	112	161	114	215	235	1977
Reggio Calabria	LICR	6	7	10	7	10	9	3	4	0	3	8	67
Olbia Costa Smeralda	LIEO	24	29	21	29	25	16	29	65	88	40	77	443
Milano Malpensa	LIMC	41	31	22	20	25	22	26	89	84	48	41	449
Bergamo Orio al Serio	LIME	6	18	12	10	25	6	8	20	36	23	40	204
Torino Caselle	LIMF	4	6	3	3	0	11	1	4	31	16	8	87
Genova	LIMJ	10	6	18	16	20	21	12	29	41	38	31	242
Milano Linate	LIML	32	6	33	19	5	10	11	58	63	53	42	332
Bologna Borgo Panigale	LIPE	9	11	15	13	13	16	8	5	27	23	30	170
Ancona Falconara	LIPY	8	11	8	11	5	8	4	2	1	1	3	62
Venezia Tessera	LIPZ	8	4	8	15	13	10	11	41	39	34	24	207
Roma Fiumicino	LIRF	13	19	32	29	25	32	38	77	53	66	71	455
Napoli Capodichino	LIRN	21	54	28	14	10	12	13	67	47	46	97	409
Firenze	LIRQ	17	25	32	22	49	90	21	30	57	45	72	460

source: Agenzia Nazionale per la Sicurezza del Volo (ANSV) - Annual reports

Table 2

Expected/Obtained Results. According to the Intergovernmental Panel on Climate Change (IPCC), in Europe, the number of airports vulnerable to potential flooding due to rising sea levels and storm surges could potentially double between 2030 and 2080, especially along the coasts of the North Sea and the Mediterranean. The IPCC also highlights a shortage of studies quantifying the impact of future extreme weather events on flight arrivals and departures at European airports (IPCC, 2022: Climate Change 2022).

Studies on wind shear phenomena, albeit cautious, have been conducted since the 1960s and have been linked to numerous airline crashes that initially appeared inexplicable. Investigations by the U.S. National Transportation Safety Board (NTSB) into the causes of these incidents proved inconclusive, although they already suggested a significant role of adverse weather conditions at that time (McCarthy, J., 2022). Professor Tetsuya Fujita was among the first to hypothesize that these incidents might be caused by wind gusts associated with lightning storms of previously unseen scale and intensity (Fujita, T., 1976; Wilson, J., 2001).

While technological systems have significantly contributed to flight safety, it took many years to achieve satisfactory results. Conversely, pilot training programs have yielded more immediate albeit modest results. These programs were made possible by the Federal Aviation Administration (FAA) and the industry's efforts, notably the Windshear Training Aid (Stratton, D.A., 1992), which focused on a better understanding of the microburst phenomenon.

During the internship carried out as part of the European Civil Protection exercise (Eu Modex 2023), a comprehensive understanding of the challenges associated with managing a large-scale emergency was acquired.

WP 2. Objective. To comprehend the limits, functionality, and key features of both onboard and ground-based technological systems, it is necessary to deepen one's knowledge through engagement with the companies that manufacture them. Research will continue in the direction of studying measures aimed at enhancing flight safety, implemented by both the United States and Europe.

Methods. In order to clarify concepts related to the technological component of meteorological forecasting, an agreement has been established with the multinational company *Leonardo S.p.A.* to undertake an internship period that will span approximately 6 months (October 2023 - April 2024).

During this time, visits to their Italian and German factories are also planned. Concurrently, a comparative analysis will be conducted between the United States' Next Generation Air Transportation System (NextGen) and the European Single European Sky Air Traffic Management Research (SESAR) plan. Surveys or interviews will be prepared for pilots, airport meteorological operators, and air traffic controllers to be administered. Procedures will need to be initiated to secure agreements with selected national and international airports to observe on-site microburst and wind shear prevention systems, both instrumental and procedural.

Expected/Obtained Results. The upcoming steps are expected to provide a much more comprehensive understanding of technological devices, delving into their operational characteristics, limitations, peculiarities, and future orientations, thanks to the internship experience at Leonardo S.p.A. Additional data and insights will be acquired through a comparison of the two plans (the U.S. plan and the European plan), allowing us to extract aspects related to safety, environmental impact reduction, and flight optimization.

Considering that no international regulation mandates airports to equip themselves with specific meteorological detection technologies, it is presumed that neither NextGen nor SESAR will introduce such a requirement. However, these systems tend to enhance communications, and alternative measures may be considered. Furthermore, airport visits will be a highly valuable component (the selection of airports will depend on the research relevance and the willingness of airports to collaborate with this research project).

- REFERENCES

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Part 2. PhD student information on the overall year activity (courses/seminars/schools, mobility periods, participation to conferences)

List of attended courses/seminars/schools

1. Design of Research: European projects – Prof. Nicola Paone (12-16-19-23-26 January 2023) – 2 CFU

2. Technology Transfer and Innovation – Prof. Donato Iacobucci (1-8-22-29 March 2023) – 2CFU

3. Methods of Disaster Research – Prof. Fausto Marincioni (22-29 March 2023, 03 May 2023) – 1 CFU

4. Getting Started with R: Environmental computing – Prof. Giuseppe D'Errico (22 – 24 – 29 May 2023) – 1 CFU

5. Regression analysis using Microsoft Excel – Prof.ssa Francesca Beolchini (23 – 25 -26 May 2023) – 1 CFU

6. Climate-related risks and extreme events – Prof. Pierpaolo Falco (12 – 15 -19 June 2023) – 1 CFU

7. Environmental Sustainability: the life cycle assessment, LCA – Prof.ssa Alessia Amato (27-29-30 June 2023) – 1 CFU

8. Human, Environmental and Geology (28 June 2023) – 1 CFU

List of attended seminars/webinars (0,5 CFU each)

1. La pericolosità sismica della regione Marche - Prof. Emanuele Tondi (DISVA seminar - 29/11/2022)

2. Laurearsi nelle tematiche del Rischio ambientale e della Protezione civile: quale figura professionale e quali opportunità di lavoro (DISVA seminar 30/11/2022)

3. Monitoring and forecasting marine heat waves - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (webinar 16/12/2022)

4. Maritime Spatial Planning in a changing climate - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (webinar 09/02/2023)

5. Agroecological practices for climate change mitigation - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (webinar 14/02/2023)

6. Mitigate wind hazards at any airports in any conditions – www.vaisala.com (webinar 18/02/2023)

7. Logistica di Protezione Civile - introduzione [Scuola Italiana Protezione Civile] (webinar 24/01/2023)

8. Ciclo: Highlander: Fuoco - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (webinar 19/01/2023)

9. Monitoraggio nel Mare Adriatico: valutare i cambiamenti ambientali per ispirare azioni di adattamento - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (webinar 09/03/2023)

10. Rischio idraulico e cambiamento climatico - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (webinar 17/03/2023)

11. Cambiamenti Climatici 2023: Rapporto di sintesi dell'IPCC-AR6 - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (20/03/2023)

12. Giustizia Ambientale in Italia - La Sapienza, Società Geografica Italiana (04/04/2023)

13. How to talk about climate change in a way that makes a difference - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (12/04/2023)

14. Environmental Intelligence - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (20/04/2023)

15. Journalism and science: narratives of climate change - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (10/05/2023)

16. Climate change and disinformation: state of the art and how to tackle it - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (16/05/2023)

17. Art and science towards climate action - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (25/05/2023)

18. A new approach-Total insights for approach area weather – www.vaisala.com (14/06/2023)

19. Exploring the Potential of Graphene Field-Effect Transistors in Biosensing for Health and Environment UNIVPM - A Shot of Science (11/07/2023)

20. CMCC Data Delivery System: Overview, Recent Advances and Future Perspectives - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (18/07/2023)

21. CCMC Coastal Resilience - Projects and actions within the UN Ocean Decade - Centro Euro-Mediterraneo sui Cambiamenti Climatici CMCC (28/09/2023).

List of attended congress (1 CFU each)

1. XII Congresso Nazionale SISMEC "Ambiente, Clima e Popolazioni" - Jesi (AN) (20-23 settembre 2023)
2. REAS – Montichiari (BS) (06-08 ottobre 2023)

List of individuals of internship

1. Individual internship: European Civil Protection Exercise "EU Modex – Arcevia 2023" (6-7-8-9 June 2023). Supervisor: President of the Association ARES Dott.ssa Barbara Gabrielli (48 h – 6 CFU).

Modex (Module Exercise) is a real-scale exercise of the European Civil Protection Mechanism (in a fictional nation called Modulistan) aimed at testing self-sufficiency scenario consisting of a combination of seismic (earthquake with magnitude of 6.8) and pandemic impacts (a significant number of patients exhibiting symptoms related to meningoencephalitis).

List of periods spent abroad

1. ///
2.

...

List of conferences/workshops attended and of contributions eventually presented

1. ///
2.

...

Part 3. PhD student information on publications

In preparation

Garbati, P., Marincioni, F. "Fenomeni meteorologici estremi in aumento: tecnologia e controllo umano per continuare a garantire la sicurezza dei voli" – Rivista di meteorologia Aeronautica

An article has been submitted to the "Rivista di Meteorologia Aeronautica" an Italian Air Force journal, highlighting the historical trajectory and technological evolution aimed at understanding the causes of aviation disasters from the 1950s to the present day.

List of publications on international journals

J1. ///

J2. …

List of publications on conference proceedings

C1. ///

C2. …

List of other publications (books, book chapters, patents)

B1. ///

B2. …

[Date] 13/10/2023

Student signature

Supervisor signature