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Weather conditions during a transatlantic flight of *Lituanica* on July 15–17, 1933

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Abstract This article focuses on the 1933 transatlantic flight of the airplane *Lituanica* and weather conditions en-route. Using reanalysis methods and comparative analysis of historiographical data, the authors aimed to restore the weather conditions and to evaluate pilots' decision-making process in rapidly changing situation during a flight from New York to Kaunas. In this study, the apparent flight path of *Lituanica* (actual flight path remains undocumented) was divided into three stages, with weather conditions investigated for each segment. The findings suggest that weather-based decision making was essential throughout most of the flight and could have played a vital role in the final stage. Over the European mainland, deteriorated weather conditions became unfavourable to maintaining the heading to Lithuania. The adverse weather had forced pilots to abandon their flight plan and consequently led to an attempted forced landing and the fatal crash in Germany.

Keywords *• Steponas Darius • Stasys Girėnas • Lituanica flight • meteorological reanalysis*

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INTRODUCTION

The flight of the Lithuanian–American pilots Steponas Darius and Stasys Girėnas over the Atlantic Ocean is considered to be one of the greatest national narratives of the 20th century and the iconic symbol of the Lithuanian identity (Bumblauskas *et al.* 2012). Both pilots were born in Lithuania, emigrated to the United States of America in their teen years, served in American Army during World War and became naturalised citizens of the USA. After the war, S. Darius (1896–1933) achieved his Captain rank in the Lithuanian air force, and conceived an idea to "hop" over Atlantics. He became even more determined when, on his way from Kaunas back to Chicago in 1927, he had witnessed a triumph of Charles Lindbergh in Paris – the first man to make a solo flight over Atlantics. In 1932, he teamed up with his countryman S. Girėnas (1893–1933), a Chicagoan businessperson and stunt pilot. They bought a serial plane *Bellanca CH–300* and rose further funding without any support from commercial companies or governments. The flight was symbolically dedicated to "Young Lithuania" and was sponsored by donations from pilots' families and major Lithuanian colonies on the Eastern coast. The remodelled plane was named *Lituanica*. The primary goal was to fly from New York to Kaunas, take rest, and hop back. Technically, the flight was hardly set for a world record, yet was considered as an extremely daring effort. Ideologically, the flight was unique: the pilots sought to break into the "elite of the elite" of modern aviators and thus to win fame, respect, and inspiration for their Motherland and Lithuanians around the world. This aim had cost them lives, and won an enduring glory of the modern Lithuanian national heroes.

Paradoxically, multiple researches into this famous story were limited regionally and thematically, and were based on (or strongly influenced by) subjective memoirs rather than on primary sources and objective analysis (e.g., Jurgėla 1935). Only once in more than 80 years a fragmentary, incomplete set of documents was published (Dariūtė *et al.* 1991). Academic publications like this one are a new trend in long–

time efforts to disclose the apparent factual complexity behind a notorious "tragic victory" of Darius and Girėnas. A reason to that is the first on–going international research (launched in 2011 in Lithuania, Germany and the USA), which reveals a new spectrum of the archival sources (Sviderskytė, 2013) and sets new tasks for today's scientists.

The documentation of two official investigations into the crash of *Lituanica* is essential for the complete analysis of this historic flight, crash and sustained aftermaths. Yet a precise study revealed that the German Report (LCVA, 1933/1) had been hastily completed in just seven days and clearly lacked thorough argumentation. The subsequent Lithuanian Act (LCVA, 1933/2) was quite analogous, though the time of investigation extended to five weeks. There are reasons to assume that both official findings did not fully unclose the primary material used by investigators, but unfortunately, most of it became sparse by being classified, lost or deliberately destructed. The package of appendix documentation, found in a Private Archive in 2012 (Sviderskytė 2012) contained "filtered" data that was directly used for and mentioned in both findings – the Report and Act. Thus, the "missing gap" in documentation of the official investigations ought to be filled by application of trans–disciplinary methods – e.g., constantly improving computer modelling and 3–D reconstructions (Štulas 1996; Sviderskytė, Silva 2013) or modern reanalysis. The latter is to be used for two reasons: to specify disputable, fragmentary described weather conditions during the flight and crash of *Lituanica*, and to form solid grounds for estimating an actual flight path of *Lituanica* from New York to crash site near Soldin, Germany (now Myślibórz, Poland).

The aircraft in flight is influenced by many different factors. Yet when it comes to *Lituanica,* the critical thinking is often being put aside, and weather conditions are blamed as a prime (if not the only) culprit of the catastrophe. This attitude was formed up in about two weeks after the crash, and it was embedded for decades, when the Act was published on October 9th, 1933: purportedly, Darius and Girėnas would gloriously reach their destination in Kaunas and certainly would not dye, *if* a stormy weather would not stop them somewhere over the Polish Corridor. Alas, it is not quite correct, because 1) earlier mishaps encountered en–route, e. g. an increased fuel consumption, could lead to fatality as well; 2) the "critical situation" mentioned (left unclarified) in both official investigations supposedly appeared *after* the pilots turned off the course, and their flight time till attempted forced landing was minimum 1.5 hours; 3) the airplane crashed near the town of Soldin, where was no storm at all; 4) in midsummer of 1933, tense political situation detained investigators from explicit, scrutinized examinations; it is obvious from numerous ambiguities and loose interpretations of the final flight leg and even weather conditions in official findings. Interestingly, the German investigators underlined human errors (fatigue, disorientation, lack of fuel) and mentioned deteriorated weather as a secondary cause (poor visibility near Soldin and more adverse weather towards the East). Meantime, the Lithuanians added possible engine disturbances caused by unclean fuel filter and especially stressed "difficult atmospheric conditions" (severe turbulence, stormy weather with rain showers near Danzig (now Gdańsk), "very bad" weather near Soldin: drizzle, low cloudiness, scattered fog and darkness). What makes these different interpretations even more remarkable is that they are based on a quite similar data (enclosed in the appendix of the official investigations; Sviderskytė 2012), provided by German, Lithuanian and American meteorologists Dr. Soultetus (first name not indicated), S. Olšauskas and J. H. Kimball, and also by the Lithuanian Aero Club representative Major V. Morkus (the latter reported: "As to weather conditions, all questioned locals said it was very dark, low clouds, and foggy. Some drizzle, but no storm. To the East, that is, near Danzig, severe lightning could be seen and perhaps thereat was a storm"). If these inadequacies would be clarified by comparing historiographical and reanalysis data, perhaps then we could move towards the trickiest puzzle: how these pilots found themselves so close to the Polish Corridor, in a knowingly dangerous region of non–flying zones and other extreme difficulties for navigation at night, and why they allegedly attempted forced landing in such a remote vicinity?

As to the actual flight path of *Lituanica,* the findings of the German and Lithuanian investigators were almost identical: purportedly, the pilots made their records on the maps during only 1/3 of the flight; their logbook allegedly disappeared; thus the flight path could be tracked down from New York to Newfoundland only; the aircraft flew to Europe unnoticed; firstly and lastly it was seen flouncing about at a risky altitude over north eastern Germany (all this was confirmed by the pilots' message dropped in Grand Falls, Newfoundland, their markings in 22 maps and other documents). However, the presented versions of the whole flight trajectory lacked solid argumentation. E.g., Lithuanian officials stated that the pilots were determined to use an alternate northern route through Scotland, yet at the beginning they flew towards London "to check their calculations" (LCVA, 1933/2). The Germans simply asserted that the pilots did not fly over London and England at all, and they certainly did not intend to reach Berlin, as "this was unnecessary" (LCVA 1933/1). In both official findings and appendix documentation (Private Archive 1933) there was not a word about the primary intended path,

which was most carefully studied by Captain S. Darius and which extended through London and Berlin; no hint that the region of crash was almost directly on the intended flight trajectory, marked on at least one map. Was this unremarked by coincidence? The alternate planned path planned by S. Darius crossed Scotland and continued over the Baltics, at northern coast of Germany. So what was his final option – intended or alternate flight path? Did pilots change their minds en–route? Did they manage to adjust masterfully to deteriorated weather conditions? On the other hand, were they "totally disoriented", as the German investigators presupposed (LCVA 1933/1)?

On the eve of the crash, it was notified that a "thunderstorm" had started to form up over the Atlantic, and weather conditions near Iceland had become severe (Jurgėla 1935; Kalvaitis 1983; Dariūtė 1990). Meteorologist J. H. Kimball of U. S. Weather Bureau in New York (he was "telling flyers when to Hop" since Ch. Lindbergh solo flight in 1927; Kimball, 1928) sent S. Darius the map indicating probable favourable weather. However, the next day, after *Lituanica* took off, he postponed the later starts due to low clouds and rainy zones over the ocean. So what was the real situation during *Lituanica* flight? How it affected human and fuel resources en–route? Did *Lituanica* fly unnoticed over Europe because of weather? Was it inevitable to fly at dangerous low altitude over Germany? To answer it, we need reanalysis of weather conditions over the Atlantic, also at the approaches of Europe and in northeastern region of Germany on July 15–17, 1933.

DATA AND METHODS

In this study, the apparent flight path of *Lituanica* was divided into three stages (Fig. 1). To avoid complexity of the time zones crossed, only Greenwich Time (UTC) was used in this text.

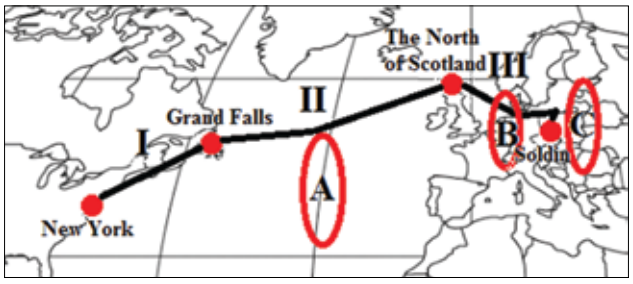

Fig. 1 The stages (I, II and III) of the *Lituanica* flight on 15–17 July, 1933. Letters indicate areas, which could affect the flight: **A** – precipitation and possible thunderstorm area in low-pressure vortex (1933 07 16, 00–12 UTC); **B** – area of low clouds and rain in the occluded front (1933 07 16 12–18 UTC); **C** – the zone of rain and thunderstorms in the atmospheric wave-front (1933 07 16, 21 UTC). More precise location of pressure systems are presented in pictures below.

The first stage was a path flown in about 9 hours on July 15; it mostly extended at the Eastern coast of the USA and ranged from Floyd Bennett Field in New York to northeastern edge of the island of Newfoundland. It was fairly recorded, marked on the maps by S. Darius in flight and descripted in both official findings.

The second stage extended over the ocean and was less documented. A remarkable distance was flown at nighttime. Actual trajectory was not marked on extant maps. No records indicated when and where the island of Great Britain was reached on July 16th. As this study showed, the pilots probably flied about 1400 km towards London; then they encountered deteriorated weather and turned north. The Lithuanian official investigators proposed the following "most reliable" version: Darius and Girėnas flew 2500 km towards London, then turned north and "overflew northern Scotland towards Kiel" (LCVA 1933/2). However, where exactly they crossed Great Britain? In this study, a northern edge of Scotland was picked (strictly conditional location, as possible as any other). Thus, the second stage ranges from Grand Falls, Newfoundland to northern edge of Scotland.

The third stage extended up to the crash site in Germany. From the point of historiography, this part of the flight path is extremely difficult to describe because of insufficient documentation and prevailing controversies. E.g., purportedly overflown locations in Germany were named by unidentified sources; both official investigations only cite same two witnesses; logbook with flight records was said to be found at the crash site and "gone". It is notable that S. Darius was warned in advance and for at least three times to avoid the northeastern region of Germany during the flight, and he was well informed that the only airports' line en–route would not operate that night (BLKM 1933). Nevertheless, the final stage of flight ended there. The Lithuanian official findings indicate four locations (LCVA 19333/2). Firstly, the aircraft was allegedly noticed (heard only) over Stargard (now Stargard Szczeciński, Poland) at 10 PM on July 16. Later at about 11.15–20 PM it was spotted circling at altitude of few hundred feet, which is dangerously low, over Berlinchen (now Barlinek, Poland). Then it was heard again at Kuhdamm (now Pszczelnik, Poland). Finally, at 11.36 PM (00.36 AM, July 17 local time) the plane crashed in a forest near Soldin (now Myślibórz, Poland). Similarly to the Lithuanian official findings, in this study it was generally presumed that *Lituanica* flew over northern edge of Scotland, then continued over the North Sea, heading to southeast towards Kiel, then turned east and flew along the southern coast of the Baltic Sea, but due to worsened weather changed to southwest (hypothetically, towards Berlin) and reached the vicinity of Soldin.

The German and Lithuanian investigators grounded their findings on at least three sources, which contained meteorological data. In 2012, these documents were found packed in one file (Private Archive 1933; a study revealed that the packed documents were appendixes, mentioned in official findings and mysteriously "disappeared" from the archives of state institutions; Sviderskytė, 2012). They had been written by three experts from Germany, Lithuania and the United States:

- Undated (not later than July 24) reference by German meteorologist Dr. Soultetus "Weather conditions over Atlantic Ocean, England and Germany on July 15–17 this year" (duplicate translated to Lithuanian);
- Undated (no later than August 30) reference signed by chief of the Lithuanian Meteorological Bureau S. Olšauskas "Weather conditions in vicinity of Berlin–Soldin at night from 7 PM July 16 to 8 AM July 17, 1933", with three synoptic charts attached;
- A letter of August 9, sent to Lithuanian consul general in New York P. Žadeikis by the U. S. Weather Bureau in New York meteorologist J. H. Kimball; also, there were extant charts signed by J. H. Kimball, which he sent to S. Darius just a few hours prior to take–off.

As aforementioned above, the German and Lithuanian official investigators underlined different meteorological factors (air pressure, precipitation, cloudiness) and drew contradicting conclusions. To our best knowledge, no further analysis was ever made after 1933. Fortunately, modern science enabled us to bring some more light into this matter.

An analysis of weather conditions requires comprehensive 3–D meteorological fields along the track of the airplane. Therefore authors decided to use the Twentieth Century Reanalysis (20CR further in the text) V2 (version 2) as the main dataset. Data here are available on sub–daily timescale from 1871. Additionally, one alternative dataset was included to the analysis – Daily Northern Hemisphere Sea Level Pressure Grids (NHSLPG). NHSLPG sea level pressure data available since 1899 and data resolution is coarser than 20CR – only 5° x 5° longitude / latitude grid. NHSLPG was used only for analysis of synoptic situation across Northern Atlantic as well as over Europe. Data access is available through Research Data Archive of the Computational and Information Systems Laboratory at the National Center for Atmospheric Research in Boulder, Colorado website – http://rda.ucar.edu/. 20CR analyses are generated by assimilating only surface pressure data and using prescribed monthly sea surface temperatures and sea ice distributions as boundary conditions within up–to date general circulation model (GCM). The GCM produces global analysis every six hours as the most likely state of the atmosphere, and an uncertainty estimate of that analysis using 56 ensemble members forecast. The model has a spatial resolution of about 200 km on an irregular Gaussian grid with 28 vertical levels and the model top is at 0.2hPa and a complete suite of physical parameterizations. 20CR also includes the radiative effects of historical time–varying CO_2 concentrations, volcanic aerosol and solar variations using the long wave and shortwave radiation models (Compo *et al.* 2011).

20CR archive suggests two types of data: ensemble mean and ensemble spread, however in current study we used ensemble mean only. 20CR data archive is an open access database, available through the NOAA Earth Systems Research Laboratory (ESRL) website http://www.esrl.noaa.gov/psd/data/20thC_Rean or through the National Energy Research Scientific Centre (NERSC) portal http://portal.nersc.gov/pydap/.

20CR troposphere data are reliable according other reanalysis datasets: NCEP/NCAR1, NCEP/DOE, ERA–40, ERA–Interim, JRA–25, MERRA etc. The largest uncertainties associated with this database identified in Polar Regions as well as in the stratospheric layers. In general 20CR data has lower level of accuracy for the period until 1940s (Brönnimann *et al.* 2012; Paek, Huang 2012).

It should be noted that reanalysis provides more information about weather conditions of the past than it was available in 1933. The meteorologists of the thirties relied on measurements of relatively rare surface meteorological stations network and not always reliable ship information (Kimball, 1928; besides, *Lituanica* flew well north from intense shipping lanes). Nowadays particularly important vertical atmospheric radio sounding then was carried out irregularly, and only in a few places in the world (the first radiosonde was launched in 1930). Modern reanalysis, based on measurements throughout more than 60 years, allowed us to restore weather conditions with sufficient precision – both over the ocean and the land surface, as well as the higher layers of the atmosphere.

RESULTS

The first stage: New York – Grand Falls (Newfoundland)

Airplane *Lituanica* piloted by S. Darius and S. Girėnas took off from New York Metropolitan Airport *Floyd Bennett Field* at 10:24 AM (UTC) July 15, 1933 heading toward the island of Newfoundland. Overflying Grand Falls the pilots threw down a message with the coordinates and UTC time 19:10 PM. While there is about 1710 km between the two points, it can be stated that in case of flying in a straight line aver-

age speed was about 195 km/h (almost the same as mentioned in the official findings of German official investigators – 190 km/h).

It is likely that the pilots flew along the North American East coast, being able to navigate visually. 20CR humidity fields show (Fig. 2) that cloudiness in the lower troposphere (up to 2500 meters) during the first stage of flight was quite low (up to 20 %). Mostly clear and maybe in some places partly cloudy weather conditions ought to allow, by today's terms, their VFR (Visual Flight Rules) flight to be relatively easy.

The fact that the weather was mostly clear was confirmed by J. H. Kimball (Private Archive 1933). He indicates that "*the flight from New York through Southern New England was under low clouds and in a head wind. Through Northern New England and on to the Newfoundland Coast the winds were helping, and the sky, mostly clear*".

Table 1 provides a short description of apparent flight route and weather conditions (based on 20CR data) during the first stage of flight. The meteorological flight conditions were good, surface pressure gradually increased; there were light wind conditions and no dominant wind direction at a height of 2–2.5 km. At the beginning, the wind blew mostly from southeast and southwest. The main zones of clouds and precipitation laid to southwest and north from flight path.

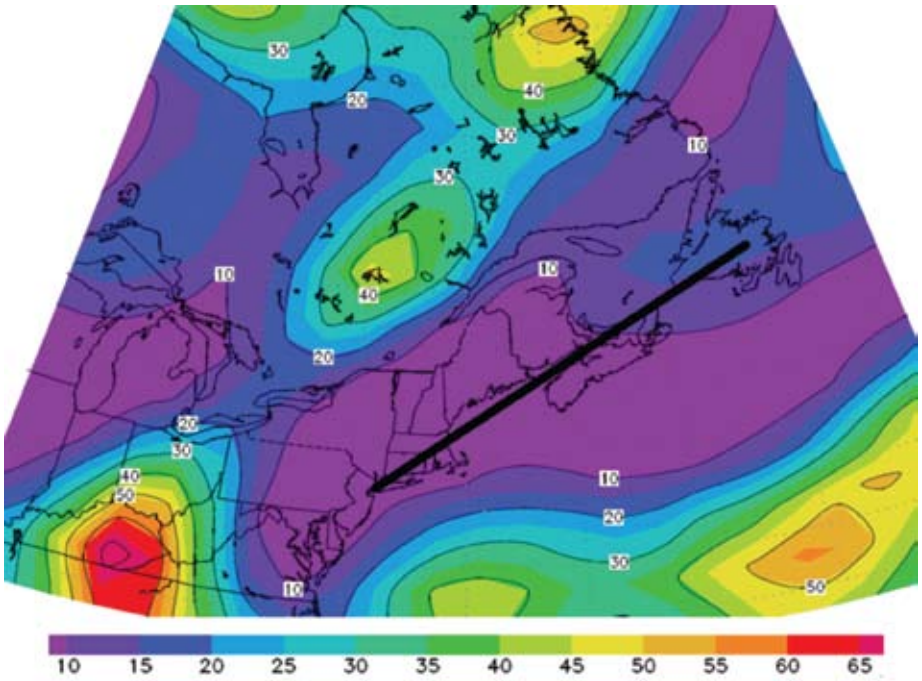

Fig. 2 The mean total cloud cover (%) in the lower troposphere (0–2500 m) at 12–18 UTC (15 July, 1933). Black line indicates the expected flight path.

Table 1 The apparent route of *Lituanica* during the first stage of flight and short description of weather conditions.

UTC time	Possible location of plane; Solar elevation angle	Weather conditions
10:24	Floyd Bennet Field airport, New York, NY 40°35' N 73°53' W; 7°	Fair weather, light wind
11:00	41°15' N 72°48' W; 14°	Fair weather, light wind
12:00	42°20' N 70°57' W; 27°	Fair weather, light south–eastern wind
13:00	43°22' N 69°01' W; 40°	Fair weather, light south–eastern wind
14:00	44°22' N 67°02' W; 51°	Fair weather, light south–eastern wind
15:00	45°21' N 64°58' W; 61°	Fair weather, light wind
16:00	46°17' N 62°51' W; 65°	Fair weather, light south–eastern wind
17:00	47°10' N 60°40' W; 63°	Fair weather, light wind of changing direction
18:00	48°01' N 58°23' W; 54°	Fair weather, moderate south and south–western wind
19:10	Grand Falls (Newfoundland) 48°57' N 55°39' W; 43	Fair weather, moderate south–western wind

The second stage: Grand Falls (Newfoundland) – The northern part of Great Britain

During the second stage, *Lituanica* crossed the Atlantic Ocean. This study assumes that the flight speed remained 195 km/h. It is likely, that initially the pilots were heading towards London. However, it is almost certain that their actual route was stretched more to north. The reason to that could be the zone of precipitation formed up in the middle of the Atlantic Ocean (Fig. 3).

Synoptic analysis of the process (based on NHSLPG data) showed that the low–pressure centre was located near coordinates 50 N–30 E and the low-pressure area deepened and gradually retreated to the north. The precipitation rate, according to 20CR data, in the low-pressure area could exceed 10 mm per 12 hours. Such amount of precipitation depends to continuous or intermittent moderate rain or shower category that could be produced by *Nimbostratus* or *Cumulonimbus* clouds systems. These types of clouds usually penetrate through lower and middle troposphere, i. e. their tops could exceed 5–6 km height. It is assumed that the pilots turned north, presumably to a much thinner cloudiness: the overloaded *Lituanica* was unable to fly over higher formations, so it had to be diverted away from the frontal cloud system; besides, this precipitation zone had to be avoided even more as it was approached in darkness. There is no reliable data about thunderstorm probability in this area. However, the analysis of the development of the precipitation field (according 20CR data) suggests that the low pressure system above North Atlantic developed on the frontal wave of the main polar front, which separates different air masses: tropical air circulating in the northern periphery of Azores High from the polar one that stretched over sub–polar and middle latitudes in the North Atlantic. It means that low-pressure system was at its earliest development phase when the heaviest rains and thunderstorms available near the peak of the frontal wave.

These and further assumptions enabled to specify more clearly the foggy statements about a *"storm of the medium strength over Atlantic"* (Kalvaitis 1983) and a legendary story of a famous American flyer W. Post, who took off from the same airport just one hour prior to S. Darius and S. Girėnas and landed safely in Germany on July 16th. It was said that *"in the evening of July 16 a severe thunderstorm extremely complicated his flight. Only the radio compass helped him out, so he was not forced to abandon his planned route"* (Dariūtė 1990). It is notable that W. Post had landed in Berlin only to refuel and attempted to continue to fly eastwards, heading to Novosibirsk. Yet in a few hours, he was forced to land in Konigsberg (now Kaliningrad, Russia) because of unfavourable weather and the next morning only he was able to continue his flight safely.

The strongest westerly and southwesterly winds were likely in the Central Northern Atlantic and over Biscayan Gulf and western France, approximately between 44 and 48 N. However, in general the mean wind speed in the lower and middle troposphere along the flight path was equal or less than 10 m/s. Moreover, the predominant wind speed during major part of the flight could be attributed to the gentle breeze category with variable wind direction and only few

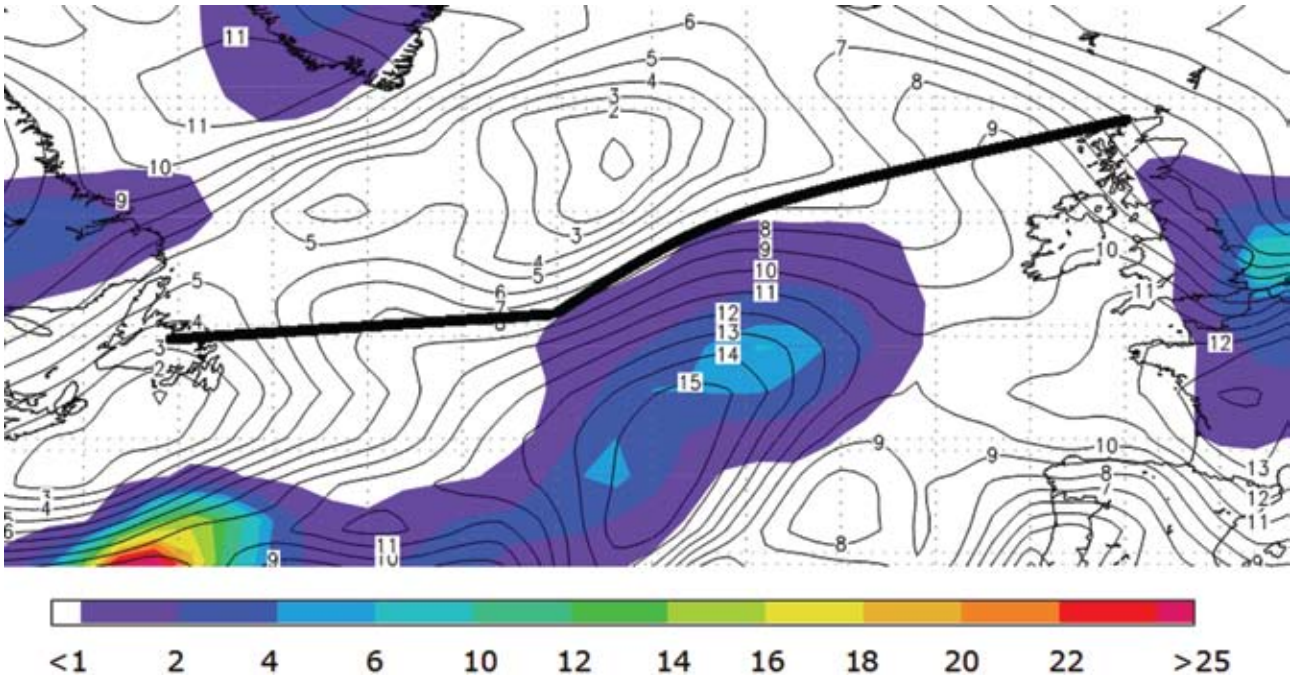

Fig. 3 The mean precipitation amount (mm/12 hours) (colours) and mean wind speed at 750 hPa level (contours) at 00–12 UTC (16 July, 1933). Black line indicates the apparent flight path.

areas show mean westerly wind speed higher than 5 m/s. A while later, approaching British Isles, the wind speed likely has increased to 10 m/s.

It is assumed that the pilots S. Darius and S. Girėnas, when flying in southwest – northeast direction, took into account the risk of getting inside the frontal clouds seen to the right of their flight route: high possibility of an increased wind speed, strong wind shear, higher fuel consumption and turbulence impact on the aircraft. Contradicting to meteorologist J. H. Kimball's statements, it could be concluded that possible low-pressure centre was located to the south and southeast from the flight route, but not to north as was emphasized in abovementioned letter (Kimball 1933). Furthermore, the developing cyclone was moving slowly to the north, so possibly the pilots gradually had directed the aircraft north-bound in order to avoid precipitation, turbulence and strong winds zones and so remaining in more favourable conditions with weaker winds and thinner clouds (Table 2). Continuing to oppose Mr. Kimball further statements that moderate to fresh winds blow from northwest during first part of the ocean and later from west and southwest, it could be demonstrated that, according 20CR data, moderate wind speed conditions were possible during short time of the flight only, and that light to gentle breezes dominated during rest of the time.

The third stage: The northern part of Great Britain – Soldin (Germany, present Poland)

This study assumes that during the third stage of flight the average speed of the plane could reduce to 170 km/h (same was concluded by German official investigators; very probably, they counted an average speed by simply evenly dividing an apparent flight path). The pilots have crossed the North Sea in south–east direction, reached Kiel and turned eastwards, and then flew towards Lithuania along the southern coast of the Baltic Sea (same assumption was made by Lithuanian official investigators). The worsening weather conditions and the storm clouds in surroundings of Kolberg (present Kołobrzeg, Poland) forced the pilots to turn southwest. This turning point is very likely, taking into an account the location of the atmospheric front (Fig. 4). According to official version coined by Lithuanian investigators, S. Darius and S. Girėnas were heading to Berlin, knowing there had to be several airports lit at night; but while on their way they encountered "critical situation" and searched for area suitable to make a forced landing. In German findings disorientation and lack of fuel were indicated as the main causes of fatal "crisis"; Lithuanians pointed out possible engine problems and adverse weather. Whatever a true cause was, the

Table 2 The apparent route of *Lituanica* during the second stage of flight and short description of weather conditions.

UTC time	Possible location of plane; Solar elevation angle	Weather conditions
19:10	Grand Falls (Newfoundland) 48°57' N 55°39' W; 43	Fair weather, light western wind
20:00	49°35' N 53°32' W; 33	Fair weather, light western wind
21:00	50°16' N 51°06' W; 21	Fair weather, light western wind
22:00	50°53' N 48°35' W; 11	Fair weather, light north–western wind
23:00	51°27' N 46°01' W; 1	Fair weather, light western wind
00:00	51°58' N 43°23' W; –7	Fair weather, moderate western and north–western wind
01:00	52°25' N 40°42' W; –13	Fair weather, light south–western wind
02:00	52°49' N 37°57' W; –15	Good, cloudy, light south–western wind
02:25	52°58' N 36°47' W; –16 Turns bit more to the north–east	The high rain clouds on the east (maybe even illuminated with lightning)
03:00	53°28' N 35°22' W; –15	Mostly cloudy, light south–western wind
04:00	54°16' N 32°48' W; –12	Mostly cloudy, light south–western wind
05:00	55°01' N 30°08' W; –5	Mostly cloudy, light south and south–western wind
06:00	55°43' N 27°23' W; 3	Mostly cloudy, light southern wind
07:00	56°20' N 24°32' W; 12	Mostly cloudy, light southern wind
08:00	56°54' N 21°36' W; 21	Mostly cloudy, possible light rain, light south–western wind
09:00	57°23' N 18°36' W; 31	Overcast, light western wind
10:00	57°48' N 15°30' W; 40	Overcast, light north–western wind
11:00	58°08' N 12°20' W; 48	Overcast, light north–western wind
12:00	58°23' N 9°08 W; 52	Overcast, moderate west and north–western wind
13:00	58°34' N 5°53' W; 53 About 13:15 reached the north coast of Scotland	Mostly cloudy, moderate north–western wind
13:50	58°33' N 3 °04' W; 49 Flew over the east coast of Scotland (in the north)	Mostly cloudy, moderate north–western wind

location of attempted landing fits well with reanalysis data on the cloudiness and precipitation: the zone between Stargard and Soldin was less cloudy.

The synoptic analysis of July 16, 1933 showed that there were two areas of active low pressure in the European domain: cyclone above South Scandinavia (old centre) and the trough over Eastern Alps and Pannonia lowland. The latter has been developing within perturbed cold front (frontal wave), which was quasi–stationary and separates two very different air masses: one warm and moist situating over Eastern Europe, and the other one, colder and drier, over

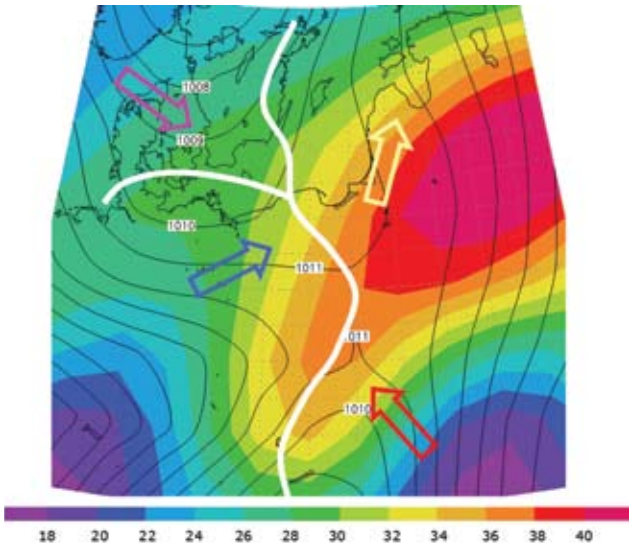

Fig. 4 The integrated water vapour content in a vertical atmospheric column (mm) (colours) and mean sea level pressure (hPa) (contours) at 6 PM UTC (16 July, 1933). White wavy line represents possible position of the main front (from south to north) and occluded fronts (from west to east) position. Coloured arrows show the prevailing air mass advection near surface: blue – cool and dry, purple – cold and wet, red – warm and dry, yellow – warm and wet.

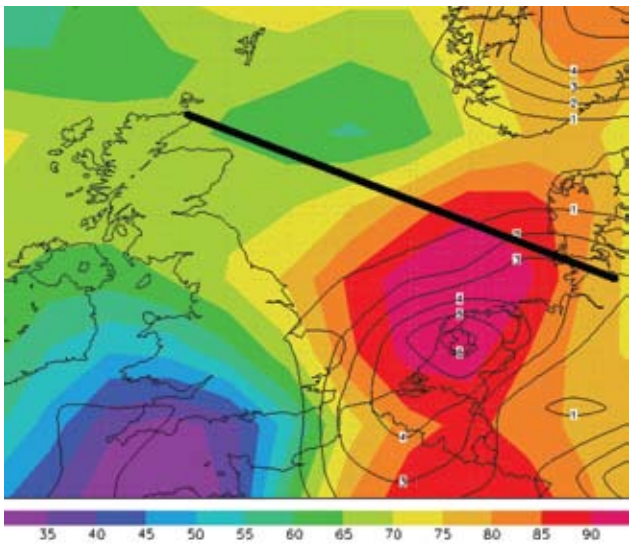

Fig. 5 The mean precipitation amount (mm/6 hours) (contours) and total cloud cover (%) (colours) at 12–18 UTC (16 July, 1933). Black line indicates the apparent flight path.

Western and Northern Europe (Fig. 4). This trough slowly advanced to northeast, producing heavy rainfall, thunderstorms and squalls, until finally decayed on July 17 and retreated further to the Russia.

At the first part of this stage, cloudiness over the North Sea gradually increased (Fig. 5). Approaching the German coast an occluded front with precipitation of moderate intensity (up to 2–4 mm in six hours) was crossed. At the coastal area, the cloudiness decreased, and it is likely that the pilots could see contours of coastline in the dusks, and thus they turned eastward along the coast.

After crossing one frontal area and seeing another, more powerful cloud zone being approached (the flashes of thunderstorm could be seen in night sky at 9–10 PM, UTC), the pilots probably turned southwest (Fig. 6A). Cloudiness decreased in vicinty of Stargard and Soldin (Table 3). It is likely that the low level clouds did not constitute a continuous layer, and the pilots managed to navigate visually by surface lights. In terms of weather conditions, it is not actually clear – why they did not attempt to reach Berlin (as the Lithuanian official investigators supposed)? Instead, they decided to attempt a forced landing in a remote area near Soldin (Fig. 6B). If at that point a "crisis" encountered earlier got even worse, it surely was *not* for the weather. In the area of an alleged forced landing there was no rain, and even some patches of clear sky could be seen. It was extremely difficult task to land *Lituanica* at night, as it had no lights. The pilots could hardly separate wooded area from plain terrain, thus they made their last turn as low as possible. The manouver was risky, and yet it could be complicated even more due to gusty western wind.

According to a survived data of meteorological stations located at this time in West Prussia and being in operational regime – Stettin (now Szczecin), Horst (now Niechorze) and Rederitz (now Nadarzyce, Poland) overcast weather with intermittent light rain and drizzle prevailed in West Prussia in midday and 6 PM on July 16, 1933. Also, south–south–westerly wind turned to the west–southwest and wind speed ranged from light to fresh breeze; ceiling from 250 m to 500 m; however, it exceeded 2500 m over the Baltic Sea coastline (Horst Meteorological Station). In the morning of July 17, low cloud cover with ceiling of about 200–300 m in all above mentioned weather stations as well as dominated westerly and south-westerly winds was recorded. Therefore, such conditions fit well with the statements made by S. Olšauskas (Personal Archive, 1933). The report of Dr. Soultetus also contained information about low cloudiness with ceiling 100–200 m which prevailed over Northern Germany. However, he made no reference to weather stations or exact location. Additionally, this report contained information about the wind in the evening of July 16:

Table 3 The apparent route of *Lituanica* during the third stage of flight and short description of weather conditions.

UTC time	Possible location of plane; Solar elevation angle	Weather conditions
13:50	58°33' N 3 °04' W; 51 Flew over the east coast of Scotland (in the north)	Mostly cloudy, moderate north–western wind
15:00	57°52' N 0°10' W; 42	Mostly cloudy, moderate north–western wind
16:00	57°08' N 2°19' E; 34	Mostly cloudy, moderate north–western wind
17:00	56°22' N 4°45' E; 24	Mostly cloudy, moderate north–western wind
18:00	55°33' N 7°02' E; 15	Mostly cloudy, moderate north–western wind
19:00	54°41' N 9°14' E; 5	Mostly cloudy, possible light rain, light north–western wind
19:25	54°19' N 10°07' E; 1 Reached Kiel, turned eastward and flew along the coastline	Mostly cloudy, possible light rain, moderate north–western wind
20:00	54°18' N 11°40' E; –4	Mostly cloudy, light rain or drizzle, light western wind
21:00	54°14' N 14°17' E; –10	Mostly cloudy, light rain or drizzle, moderate south–western wind
21:30	54°10' N 15°36' E; –12 Reached surroundings of Kolberg and turned south–westward	Rain, thunderstorm flashes in high and thick cumulonimbus clouds can be seen in the East, moderate south–western wind
21:30 – 23:36	Approached Stargard 53°20' N 15°02' E; –14. Looked for a place to land between Stargard and Soldin. Crashed near Soldin 52°52' N 14 °50' E; –14	Partly cloudy, light rain or drizzle, moderate probably gusty western wind.

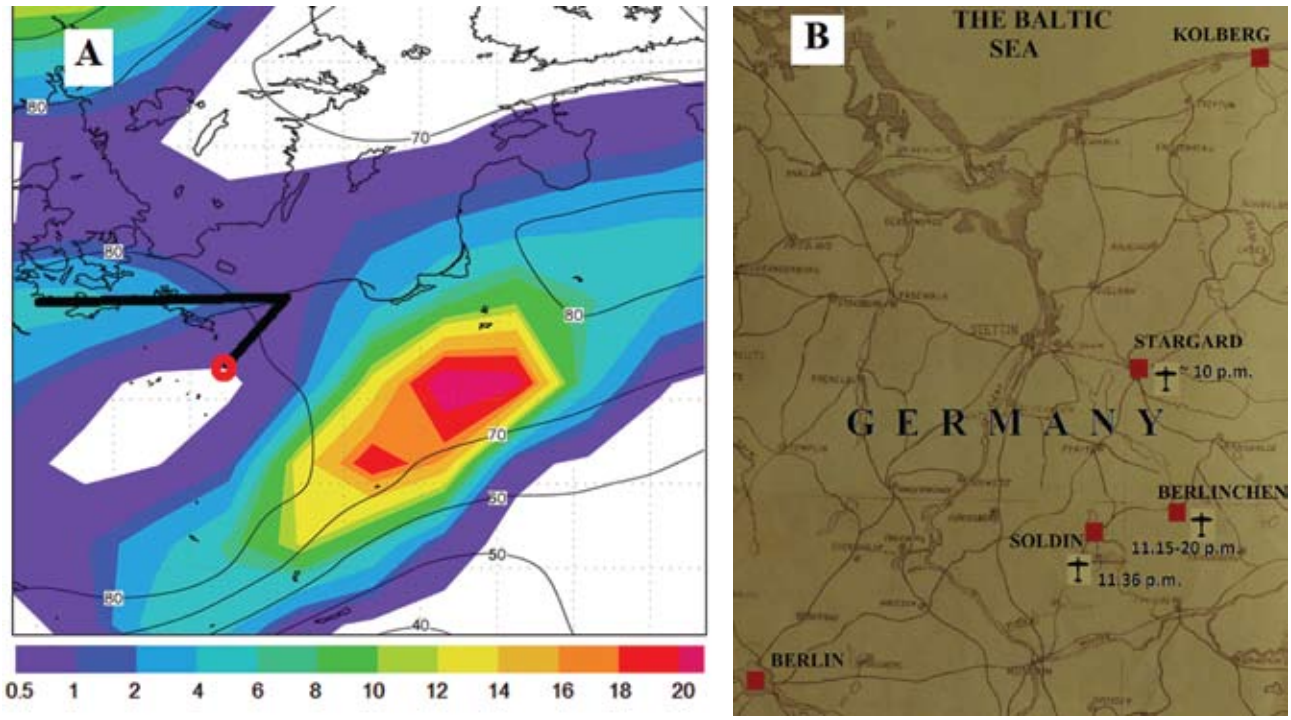

Fig. 6 The mean precipitation amount (mm/6 hours) (colours) and a relative humidity (%) at 900 hPa level (contours) at 18–24 UTC (16 July, 1933). Black line indicates the expected flight path. **A** – the red dot marks the crash site; **B** – the more detailed map of the crash site (near Soldin) area with indicated location of *Lituanica.*

purportedly, direction has changed from west to northwest while speed remained almost unchanged. Nevertheless, the changes in prevailing wind direction usually take place during atmospheric front passage and at the moment of such passage the wind usually become gusty or is accompanied by squall. The mismatches between wind regime described in the report and data derived from weather stations archive may occur due to specific observation time schedule at weather stations: last observations of particular day were used to be made at 6 PM, followed by next observations only in the morning (6 AM) of the next day.

DISCUSSION

According to 20th Century Reanalysis output, the large scale circulation over Northern Atlantic during 15–16 July of 1933 seemed to be "close to normal": Azores High was located within its climatological position while low pressure centres migrate north from it, except the active frontal zone interposed between North America coastline and Azores High; however, this area was beyond the flight route. Both foreign experts, J. H. Kimball and Dr. Soultetus have reported about favourable wind conditions over Atlantic: at most of the flight time the pilots flew downwind, while stronger wind and wind shear fields remained southward from their path. Presumably, that was corrected during the flight, in accordance with visible signs of atmospheric disturbances.

J. H. Kimball attempted to summarize the large–scale atmospheric circulation conditions known for that moment and to assess the contribution of the human factor. Moreover, he pointed out that weather maps were prepared and sent to Mr. S. Darius in time: as the provided data did not contain any extraordinary information about weather conditions, along the flight section neither between New York and Newfoundland, nor over Atlantic and the North Sea, except the narrow poor weather band over Central North Atlantic. This poor weather area started to develop in July 13 eastward from Newfoundland and was well known for the transatlantic flyers. Therefore, J. H. Kimball quite reasonably gave permission to "hop". However, the pilots had to notice wide and high band of the frontal clouds to the southeast of the provided trajectory and could decide to change the course towards the northeast or north.

Weather conditions for the section between British Isles and West Prussia were described in a slightly different mode. The reports of Dr. Soultetus and S. Olšauskas were mainly focused on weather conditions prevailing in Germany at the moment of plane crash. Despite the more professionally coined description by Dr. Soultetus, Mr. S. Olšauskas surpassed his German colleague by adding three detailed synoptic charts (comparing to 20CR data) for the Europe. These charts included accurate position of surface high and low centres, meteorological observations marked by special symbols, isobars etc.

The apparent mismatches of the meteorological information (wind field, precipitation type and intensity, etc.) provided by three different meteorologists could be influenced by following factors: uncertainty about the flight trajectory between Newfoundland and Germany, insufficient available observations over the ocean and North Sea, as well as by absence of conventional meteorological night time observations. The German investigators used the report of Dr. Soultetus, Lithuanians were provided with all three reports. So it is very likely that at least some of the abovementioned distinctive interpretations in their findings were caused by these mismatches.

Summarising information available in all three meteorological reports, the weather information sent to pilots prior to take–off, and an assessed meteorological fields extracted from 20CR dataset, we can conclude that complicated weather conditions prevailed over Eastern Europe during late hours in July 16, 1933 and bad weather signs were clearly visible ahead of the planned flight route. The *Lituanica* was not equipped with the radio, so pilots S. Darius and S. Girėnas were not supplied with in–flight information. That is, they had to make their decisions by compiling a pre–flight weather information and visible observations en–route. On the final stage of their flight, the piloits were forced by an adverse weather to radically change heading and abandon their general flight plan. It is likely that initially they hoped to go round the storm clouds from south. Shortly they realized that the scale of storm clouds is much larger than localized system of convective clouds. They could estimate that a system like this could span hundreds of miles. Therefore, they decided to land in Germany (presumably, in Berlin, but more likely as soon as possible) and looked for an area with at least better visibility conditions, i. e. where the wider breaks in a uniform and continuous cloud cover could be seen. Weather conditions had changed in this particular area in the afternoon and night of July 16: cooler and drier air mass was followed by rain and was favourable for quite thick radiation ground fog formation (2–5 meters). A fog like this is almost transparent from the birds–eye perspective. But when the pilots kept low interception angle just a few meters above the top level of the fog, it became a "a grey soup" with no visual reference to the ground.

If the German and Lithuanian investigators had reported the impact of weather conditions on a flight of *Lituanica* referring only to abovementioned reports and had no other appreciable qualitative information, then the differences in their interpretations of weather conditions (and consequently affected conclusions regarding the cause of the crash) could be explained as follows.

Professional information provided by German expert was more detailed than the one of the Lithuanian meteorologist. Additionally prevailing low cloudiness in the late hours of July 16 was reported by several meteorological stations located in West Prussia, while detailed synoptic charts (synoptic schemes according current understanding) were presented in the annex of Lithuanian report and special symbols and signs indicated similar weather conditions in July 16 as well as in the morning of July 17.

Finally, one question was left unexamined. The German meteorologist has mentioned a difference in atmospheric pressure in sites where *Lituanica* took–off and crashed – respectively, 761 and 755 mm. Dr. Soultetus claimed that the pressure in New York was by 6 mm higher than near Soldin and consequently the aircraft altimeter indicated the higher absolute altitude by 70 meters. However, it is not entirely clear whether the German meteorologist meant the pressure (755 mm) at sea level or at crash site. It is very likely that the pressure at sea level was indicated (according to reanalysis the sea level pressure was 756.7 mm at zero UTC). Also, it is necessary to draw attention to the absolute altitude difference (about 7 m above sea level at the New York airport and about 70 m at the crash site), i.e. very similar height difference with the aforementioned. If Dr. Soultetus indicated pressure at sea level, the altimeter was indicating somewhat correct height above the surface. If Dr. Soultetus indicated pressure at the crash site, then the altimeter of crashed plane had to stop at the 60–70 m mark. In any case, this resulted in even more difficult conditions for landing. On the other hand, in theory, the pilots were able to realize the terrain height (they had a map with the marked line of the primary flight path, which almost crossed the catastrophe location). But practically it was difficult or, more likely, impossible to being assessed in a stressful situation (dark and cramped cabin, fatigue, possible lack of fuel, absence of landing lights, no in–flight information, etc.). It could be argued (only by guessing) that a highly experienced flyer like Captain S. Darius (who was *Lituanica's* first pilot and main navigator) had to understand and assess situation sufficiently ant that in a life-or-death situation the pilots' decision making just could not be entirely tied up to altimeter readings. And so, finally, it has to be assumed that the unknown terrain altitude and atmospheric pressure was just one of the reasons that had led to the crash of *Lituanica*.

CONCLUSIONS

During the *Lituanica* flight from July 15 to 17, 1933, the large scale atmospheric circulation over North Atlantic was "near normal" – no anomalous airflow patterns were detected using given synoptic charts and 20 century reanalysis fields. Much more complicated weather conditions prevailed over Europe: low cloudiness over North Sea and Northern Germany and active atmospheric front from southern Baltic to Carpathians mountains.

An actual flight path of *Lituanica* could have been changed significantly at several points by precautionary weather decision making by Captain S. Darius, who was the first pilot and chief navigator of the transatlantic flight. The reanalysis data did not contradict the statements by official investigators who claimed that: a) *Lituanica* could pass the British Islands being unnoticed because of the thick clouds (German Report); b) the airplane possibly had crossed the narrow northern edge of Scotland (Lithuanian Act of Investigation).

The findings of the study append more detailed information to the three references by the American, German and Lithuanian meteorologists, which were provided to the official investigators in 1933. Accordingly, it explains the differences in assumptions made by the German and Lithuanian officials. It also clears up the vagueness in the Lithuanian officials' conclusion about a "very bad weather" at the vicinity of the crash: weather conditions could hardly be a reason to a worsened "crisis", which allegedly had led to a forced landing near Soldin.

According to this research, the most likely cause of the *Lituanica* crash could be a poor visibility due to low clouds and probable foggy conditions under clouds at the nighttime hours, and a human factor, that is, presumably faulty orientation in space.

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REFERENCES

Private Archive (not specified by owners' will), uncatalogued documents: Kimball J. H. 1933. *Letter to the Lithuanian Consul General in New York Povilas Žadeikis,* the U. S. Department for Agriculture, Weather Bureau New York, 2 pp.; Olšauskas, S., 1933. Weather conditions in Berlin and Soldin at night from 7 p. m. July 16th to 8 a. m. July 17th. *Reference from Meteorological Bureau*, Kaunas, 1 pp., *charts*, 3 pp.; Dr. Soultetus, 1933, Weather Conditions Over the Atlantic

Ocean, England and Germany on July 15th to 17th this year. *Reference*, Germany, 1 pp.; Morkus, V., 1933, *Report from Soldinen Stadt Forst with an attached scheme of the crash site*, Kaunas, 2 pp. [In Lithuanian].

Balzekas Museum of the Lithuanian Culture (Chicago, USA), Collection of Darius and Girenas, uncatalogued documents: letters to Steponas Darius by Prof. Zigmas Žemaitis, Chair of the Lithuanian Airclub, 1933–01–17, 1933–04–10, 4 pp.; letter by chief commander of the Lithuanian Air Force, Col. Stasys Pundzevičius, 1933–04–04, 2 pp. [In Lithuanian].

Brönnimann, S., Grant, A. N., Compo, G. P., Ewen, T., Griesser, T., Fischer, A. M., Schraner, M., Stickler, A., 2012. A multi–data set comparison of the vertical structure of temperature variability and change over the Arctic during the past 100 years. *Climate Dynamics 39*, 1577–1598. http://dx.doi.org/10.1007/s00382–012–1291–6

Bumblauskas, A., Eidintas, A., Kulakauskas, A., Tamošaitis, M., 2012. *History of Lithuania*. Vilnius University Publishing House, 173 pp. [Lietuvos istorija; in Lithuanian].

Compo, G. P., Whitaker, J. S., Sardeshmukh, P. D., Matsui, N., Allan, R. J., Yin, X., Gleason, B. E., Vose, R. S., Rutledge, G., Bessemoulin, P., Brönnimann, S., Brunet, M., Crouthamel, E., Grant, A. N., Groisman, P. Y., Jones, P. D., Kruk, M., Kruger, A. C., Marshall, G. J., Maugeri, M., Mok, H .Y., Nordli, P. Ø, Ross, T. F., Trigo, R. M., Wang, X. L., Woodruff, S. D., Worley, S. J., 2011. The Twentieth Century Reanalysis Project. *Quarterly Journal of the Royal Meteorological Society 137*, 1–28. http://dx.doi.org/10.1002/qj.776

Dariūtė–Maštarienė, N., 1990. *Darius and Girėnas*. Vilnius, 318 pp. [In Lithuanian].

Dariūtė–Maštarienė, N., Gamziukas, A., Ramoška, G., 1991. *Darius and Girėnas. Documents, Letters, Memoirs.* Kaunas, 163 pp. [Darius ir Girėnas. Dokumentai, laiškai, prisiminimai; in Lithuanian].

Jurgėla, P., 1935. *Winged Lithuanians Darius and Girėnas. Their Lives and the First Transatlantic Flight of Lithuanians from America to Lithuania.* Chicago, 384 pp. [Sparnuoti lietuviai Darius ir Girėnas. Jų gyvenimai ir pirmasis lietuvių skridimas per Atlantą iš Amerikos į Lietuvą; in Lithuanian].

Kalvaitis, A., 1983. Tragic Victory of Darius and Girėnas. *Technikos žodis 2,* 3–7. [Dariaus ir Girėno tragiška pergalė; in Lithuanian].

Kimball, J. H., 1928. Telling ocean flyers when to hop. *Popular Science Monthly 8,* 117–118, 136.

Documents from the Lithuanian State Central Archives (LCVA): 1. Usinger, Hattendorff, Baumert, 1933. Report from Brandenburgh province Berlin Oberprezident's office, L. u. 1119/33, Charlottenburgh, 1933–07–24. LSCA, f. 383, ap. 7, b. 1471, p. 25–34. 2. Gustaitis, A., Morkus, V., Reimontas, V., Gavelis, A., 1933. The Act of the conclusions of the official investigation, completed by a subcommittee led by the head of the Technical department of the Lithuanian Air Force, Colonel Lieutenant Antanas Gustaitis. Original undated. LSCA, f. 383, ap. 7, b. 1471, p. 49–54. [In Lithuanian].

Paek, H., Huang, H. P., 2012. A comparison of interannual variability in atmospheric angular momentum and length–of–day using multiple reanalysis datasets. *Journal of Geophysical Research 117*, D20102. http://dx.doi.org/10.1029/2012JD018105

Štulas, S., 1996. Modern technologies in researching and popularising the transatlantic flights. (Thesis of the conference) *The Problems of the Researching of S. Darius' Achievements and his Commemoration,* 36–46. [Modernios technologijos tyrinėjant ir populiarinant transatlantinius skrydžius; in Lithuanian].

Sviderskytė, G., 2012. The „lost" appendixes of the Act of the official investigation into the crash of „Lituanica". *Naujasis židinys–Aidai* 7, 478–483. [„Dingę" *Lituanicos* katastrofos oficialaus tyrimo Akto priedai; in Lithuanian].

Sviderskytė, G., 2013. The official investigations into the crash of "Lituanica" in 1933: New facts and insights. *Lietuvos istorijos studijos 31*, 98–114.

Sviderskytė, G., Silva, E., 2013. "Lituanica–3D": The reliques transformed into an object of research. *http://www.lituanica–documentica.lt/index.php?id=300* [„Lituanica–3D": relikvijos tampa tyrimo objektu; in Lithuanian].