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Civil Aviation Experience for the Air Force: The Impact of Global Climate Change on the Selected Parameters of the Cessna Citation XLS+

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***Abstract*—This paper deals with the civil aviation experience focused on the impact of global climate change on the operational and performance parameters of the Cessna Citation XLS+ aircraft and consequently on the whole aviation. The aim of this article is to do a research, study and analyze the influence of the global climate change (especially temperature changing – warming up) on this aircraft type performance and make an evaluation and conclusion for how it can affect the operation, economy and safety of the air traffic flow management. The theoretical and practical part of the article includes a system analysis of temperature changes and operational performances of the selected type of aircraft. The result and benefits of the paper is a response on the current issue: how the global climate change can influence the Civil/ Military aircraft operational parameters. This experience is also a part of the Knowledge Alliance of Aviation Education. The perspective international Expert Database of Civil and Military Aviation Experience is still in progress.**

Keywords-components; aircraft performance, cesna citation, fuel consumption, global climate change, meteorology, temperature, wind

I. INTRODUCTION

Aviation education as an interdisciplinary didactic system, within the framework of the state educational policy for the 21st century" is expressed in the description of a new proposal of the Field of Study 6 Transport. The global climate change is a very actual and disputable topic in the recent days. It globally affects the Earth´s aviation transport. NASA claims: "The Earth´s average temperature has increased about 2 degrees Fahrenheit during the 20th century. Two degrees may sound like a small amount, but it´s an unusual event in our planet´s recent history." [1,3]. The global climate change causes more intense heat waves, which has a negative impact on the aircraft performance and consequently on the aviation. This paper deals with this world wide issue.

II. GLOBAL CLIMATE CHANGE ON THE WHOLE WORLD

The climate, weather on the Earth is gradually changing, warming up, which has a negative impact on the environment – ice on lakes and rivers breaking up earlier, glaciers have shrunk, trees are flowering sooner. "The scientists have high confidence that global temperature will continue to rise for decades to come, largely due to greenhouse gases." as in [2,3] The potential future effects of global climate change include more frequent tropical storms, extreme weather, hurricanes, precipitation, heat waves, and longer periods of drought in some regions.

The heat waves are periods of abnormally hot weather lasting days to weeks and have become more frequent in recent decades. This causes higher temperature, stronger tropical storms, hurricanes and extreme weather. The following two pictures describe the weather change (especially the average yearly temperature change from 2010 to 2017 (Figure 2)) on the earth. [5]

On the basis of meteorological measuring and observation it is clear, that the global air temperature on the Earth increased in average by a +0,9 °C to 2017. During the last seven years the average global temperature from 2010 (the average temperature deviation from normal was +0,70 °C) to 2017 increased by a +0,20 °C. In 2011 the average temperature deviation from normal was +0,57 °C, in 2012 it was +0,61 °C (+0,04 °C more), in 2013 it was +0,64°C, in 2014 the average temperature deviation was +0,86°C, which is a rapid increasing in one year (+0,22°C more) – it is clear from Figure 1. In 2016 the temperature deviation from normal was +0,99 °C (+0,13°C more). [4]

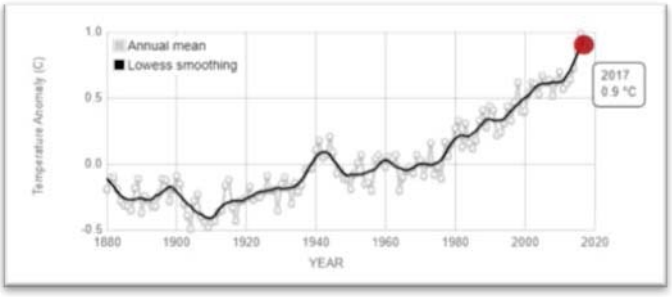

Figure 1 Global temperature change [4,5]

The Figure 2 shows on the fact that the temperature in the last 18 years are gradually raising and warming up. The rapid average temperature increases are recorded from 2015.

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Figure 2 The deviation of the world average yearly temperature from normal in the last 18 years [2]

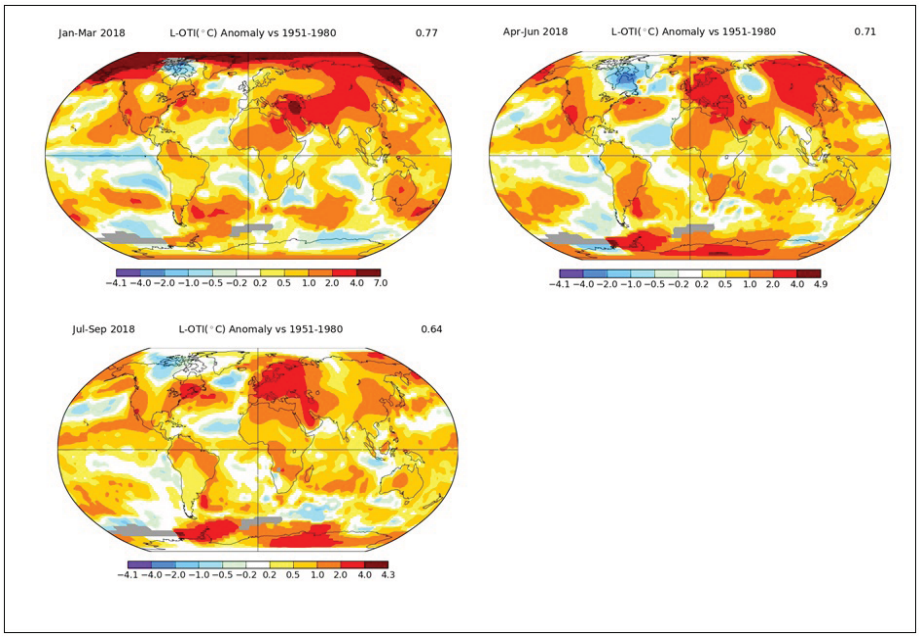

Figure 3 Temperature anomalies in 2018 [2,7]

The global climate change situation in 2018 is on the Figure 3. The Figure 3 shows on the fact that there were anomalies on the Earth in the year 2018. The values are in °C. Only 3 quarters are stated on the picture. The 1st quarter is related to the month from January to March, the 2nd is from April to Jun and the 3rd is from July to September. In the 1st quarter the temperature deviation, comparing to normal (1951-1980) was greater than in the 2nd and 3rd quarter. The anomaly values were 0,77 °C in the 1st quarter, 0,71 °C in the 2nd quarter and 0,64 °C in the 3rd quarter. It is clear from the picture that the global temperature is gradually changing from the long lasting normal (1951-1980 regarding to quarters in years) in 2018. The scientists predict that increasing global temperature change and warming will continue.

III. THE TEMPERATURE AND WIND COMPONENT IMPACT ON THE OPERATIONAL PARAMETERS OF C560 XLS+

This third chapter analyses operational parameters of the aircraft in different meteorological condition during landing configuration and en-route flight.

Generally it is true, that air temperature lower than ISA positively affects the A/C performance. It is caused by the fact that air density is increasing with temperature and decreasing at low pressure and high temperature. The engine thrust increases in high air density and the current fuel consumption increases, too. The exact explanation is the following:

- The fuel consumption is indirectly proportional to the temperature and directly to air density.
- With higher temperature the A/C flies worse, but with lower current consumption.
- With the rising temperature, the temperature inside the engine increases and consequently the engine control unit decreases the RPM (revolution of the engine) to avoid exceeding the temperature limits inside the engine. This continues to decrease the current fuel consumption and also a power of engine, which is not desirable. [5]

When the A/C flies slower (because of the worst engine performance) with a lower current fuel consumption, then the total fuel consumption can be higher than the flight with higher speed and higher current fuel consumption.

The total and specific fuel consumption depends on many other factors, like wind component.

The headwind positively affect the aircraft performance in landing and take-off configuration, but negatively effect on the en-route flight - increasing the duration of flight and consequently the total fuel consumption. For the en-route flight the ideal wind is a tail-wind component.

The above mentioned and theoretically explained fact is shown and confirmed with the next practical simulated models.

A. First model – the operational parameters of the C560 XLS+ aircraft and fuel consumption in cruise climb to 10 000 ft at retracted landing gear (anti-ice systems off)

Figure 4. proves that the aircraft fuel consumption is 184 LBS in ISA+20°C, 151 LBS in ISA+10 °C, 136 LBS in ISA and 127 LBS in ISA-10 °C, when the take-off weight of the A/C is 19 000 LB (the actual aircraft weight at take-off without the taxi fuel). The rate of climb is 1 995 FPM in ISA+20 °C, 2 749 FPM in ISA+10 °C, 3 557 FPM in ISA and 4 501 FPM in ISA-10 °C.

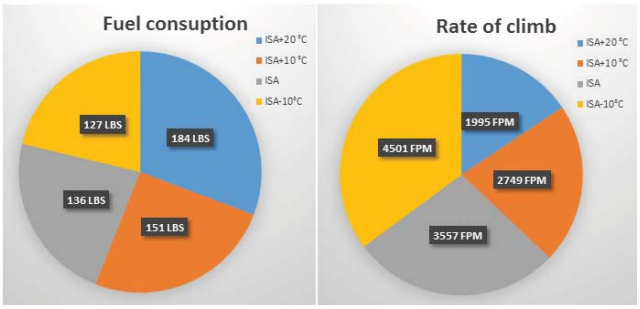

Figure 4 Fuel consumption and rate of climb [own, 9]

Figure 5. shows the fact that the distance in NM to 10 000 ft is 20 NM in ISA+20 °C, 14 NM in ISA+10 °C, 12 NM in ISA and 11 NM in ISA-10 °C. It means, that during a 4 minutes climb with a 1 995 FPM rate of distance the A/C flies 20 NM and consumes 184 LBS fuel in ISA+20 °C. It is by a 48 LBS more than in the ISA condition and the rate of climb is by a 1 562 FPM worse than in ISA.The required height reaches in 4, 3 and 2 minutes. [9]

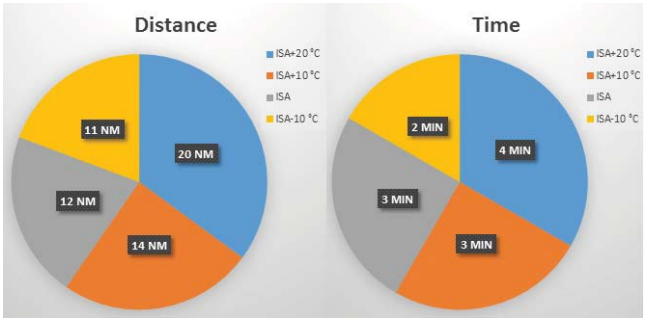

Figure 5 Distance and time [own, 9]

The above mentioned graphs demonstrate the theoretical fact, that the fuel consumption is higher in warmer air at cruise climb because of the lower power thrust in engines. But during en-route flight the current fuel consumption is opposite (2. model).

The wind component affects the climb and has the following impact:

TABLE I. WIND COMPONENT [9]

Time of climb (min)	Wind		
	25 kt	50 kt	100 kt
5	2	4	8
10	4	8	16
15	6	12	25
20	8	16	33
25	10	20	41
30	12	25	50

The wind impacts the time of climb and length of the distance. It is a key factor for choosing the take-off and landing RWY direction.

B. Second model – the operational parameters of the C560 XLS+ aircraft and fuel consumption during en-route flight at FL 450 (anti-ice systems off)

The second model confirms the fact mentioned in the Chapter 2 – the air temperature increases, the current fuel consumption decreases during en-route flight.
During en-route flight the fuel flow is lower in warmer air mass, because of the lower air density (Figure 6.).

For example, I have chosen the FL430 for which the weight of the aircraft is 18 000 LBS.

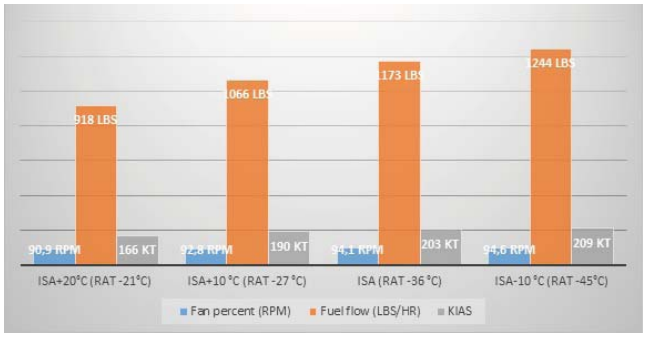

Figure 6 Fuel flow per hour in FL430 [own, 9]

Figure 6. demonstrates that the fuel flow per hours is the highest in ISA-10 ° C and the lowest in ISA + 20 °C condition in en-route flight configuration, but the engine power in RPM is worse and the IAS is lower in warmer air mass. It means that the aircraft will fly longer with lower current fuel consumption. The resulting effect (total fuel consumption) depends also on the wind component (Figure 7.).

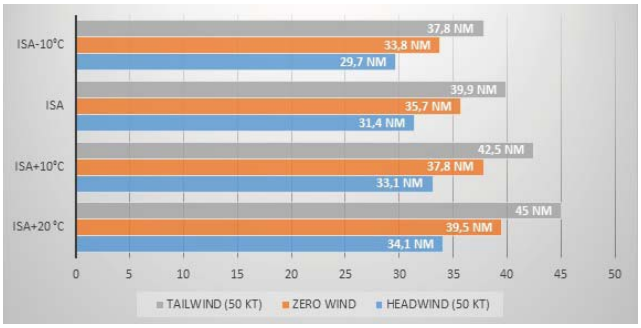

Figure 7 The wind component effect on the en-route flight at FL 430 [own, 9]

The Figure 7. demonstrates that during en-route flight the tailwind favorably affects the flown distance per 100 LBS. While during take-off and landing the headwind decreases the required RWY length for landing/take-off and the fuel consumption, so during en-route the distance and the fuel consumption increase, too.

CONCLUSION

This experience is also ***a part of the Knowledge Alliance of Aviation Education***. It presents the know-how, past and present aviation experience, the results of the theoretical work and the scientific and research activities in the field of :

- Academic subjects,
- Simulation and modelling of Security issues, as in [10-14],
- Technical Sciences, as in [15-17],
- Military / Air Force management, education and training etc. , as in [18-23].

The educational resources for more detailed study are available at the university library or on-line open access / e-learning modules, MOOC Massive Open Online Courses. The perspective **Expert Database of Civil and Military Aviation Experience** based on the strong Military /Air Force management and Military Technology is still in progress.

The global climate change has a great impact on the environment and aviation too. The environment and aviation is closely related, because aircraft produce carbon dioxide, which contributes to the greenhouse effect and consequently to the global warming issue. In warmer air the aircraft flies slower and longer with current lower fuel consumption, but the resulting effect is the opposite. This is confirmed in Chapter 2 - The temperature and a wind component impact the operational parameters of C560 XLS+, where I analyzed (I was dealing with this issue during my diploma research – which has a title: The influence of global climate change on the European aviation) the operational parameters of the aircraft in different temperature conditions. The flight endurance extension leads to more delays and congestions and more carbon dioxide production at airports. The carbon dioxide levels in the air will be the highest in 650 000 years.

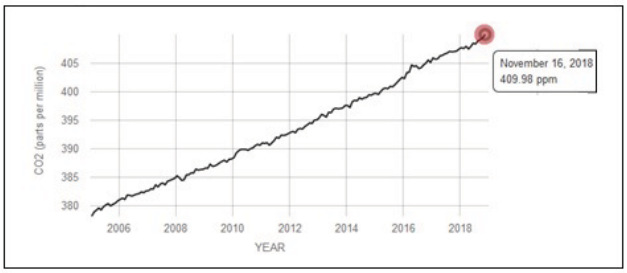

Figure 8 Carbon dioxide data [1]

To this day (10.01.2019) it has reached 410 ppm (parts per million) and it is still rising.

"The average global temperature in November 2018 was 1.35 °F above the 20th century average of 55.2 degrees. This was the fifth-highest temperature for November (tying with 2004 and 2016) in the 139-year record (1880-2018)." [6]

NOAA has a selected significant anomalies and events which have occurred in November 2018 (Figure 8):

- the arctic sea ice extent was 8.4 % below the 1981-2010 average
- cooler than average conditions were present in North America and warmer than average temperature were present in Alaska and western parts of Canada
- the Europe´s November 2018 temperature was the 11th highest on record
- the Hawaii region had its 3rd highest November temperature on record, Africa the 6th highest on record, the Caribbean Islands the 11th highest on record, Europe temperature was the 11th highest on record, South America has the 8th warmest since 1910
- an intense heat wave affected northern Queensland
- below average precipitation was observed in Island of Fiji.

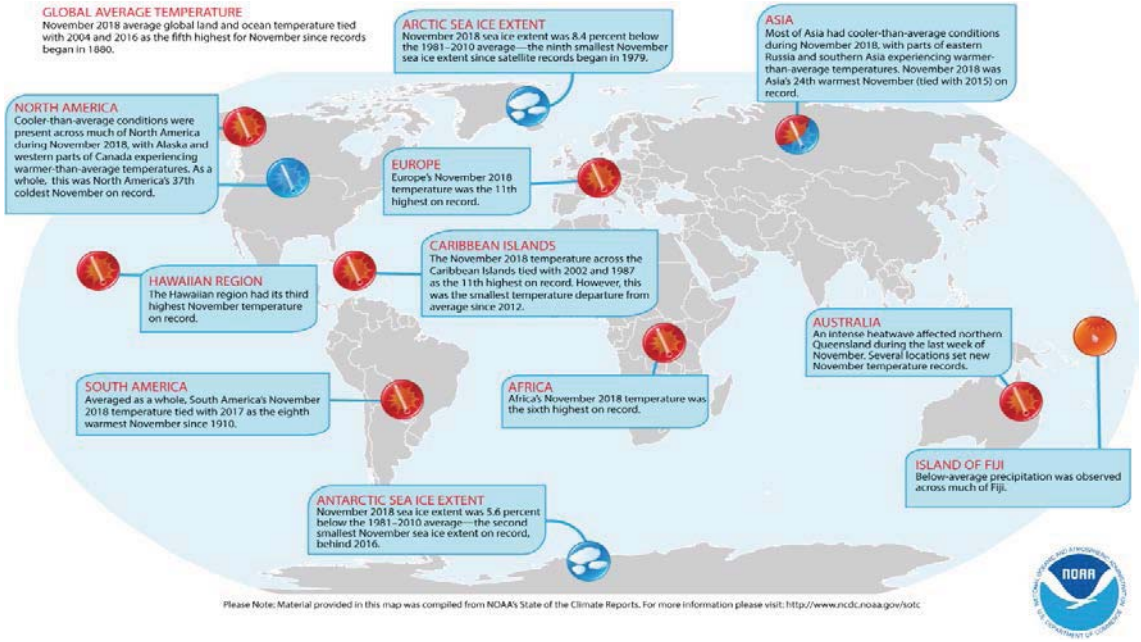

Figure 9 Selected significant climate anomalies and events in November 2018 [6]

The every above mentioned anomaly indicates a very actual and dangerous global problem, which concerns everyone. For this we need to make action and the humanity must significantly reduce the amount of heat-trapping emissions – develop aircrafts engines, which produce less carbon dioxide gases, reduce fuel consumption and the flight time endurance.

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