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THE ANALYSIS OF AIRCRAFT IMPACT ON MICROCLIMATE CHANGE AT AIRPORT AREA

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The paper contains the analysis of major factors inducing climate changes at local level of airports. The atmosphere structure and technical conditions of supersonic and subsonic aviation flights are shown to have influence on the consequences of air pollution caused by aircrafts. The potential impacts of aviation induced pollution are studied based on the concept of radiative forcing in relation to the major substances affecting energy balance of the atmosphere. Impacts of typical greenhouse gases were considered as well as specific effects of their chemical transformations for territories microclimate alterations. The conditions of contrails and cirrus clouds formation were analyzed. The cirrus clouds together with carbon dioxide emissions were set to play noticeable role in microclimate temperature component smoothing and induction of unpredicted weather phenomena and deviations in precipitation regime. The results of temperature increase assessment at certain Ukrainian airports are presented.

Key words: air pollution, airport, microclimate, greenhouse effect, radiative forcing.

АНАЛІЗ ВПЛИВУ ПОВІТРЯНИХ СУДЕН НА ЗМІНУ МІКРОКЛІМАТУ В ЗОНІ АЕРОПОРТУ

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Проаналізовані основні чинники, що викликають зміни клімату на місцевому рівні аеропортів. Показано, що наслідки забруднення атмосфери повітряними суднами залежать від будови атмосфери та технічних умов необхідних для польотів надзвукової та дозвукової авіації. Потенційні впливи на навколишнє середовище, спричинені авіацією, досліджувались на основі концепції радіаційного впливу основних забруднювачів, що мають здатність впливати на енергетичний баланс атмосфери. Розглянуто вплив типових парникових газів, а також специфічні наслідки їх хімічних перетворень, що призводять до зміни параметрів мікроклімату території. Вивчено умови утворення інверсійних слідів повітряних суден і перистих хмар. Встановлено, що перисті хмари разом з викидами вуглекислого газу відіграють важливу роль у зменшенні перепаду температур на території аеропорту, призводять до виникнення непередбачуваних погодних явищ і відхилень в режимі опадів. Представлені результати оцінки підвищення температури для ряду українських аеропортів.

Ключевые слова: забруднення повітря, аеропорт, мікроклімат, парниковий ефект, радіаційний вплив.

PROBLEM STATEMENT. Airports are considered to be one of major stressors for the environment due to immense chemical and physical pollution. The sources of these negative impacts are found both on the ground and in the sky. Effects of ground facilities and vehicles are understandable and relatively well studied. As for the flying aircrafts typically the main environmental concerns associated with them are:

– climate change

– stratospheric ozone reduction, leading to increased surface UV radiation

– regional pollution - changes in troposphere chemistry for tens to hundreds of kilometers downwind of the airport.

– local pollution - both noise and decreased air quality caused by aircraft in the ground layer of atmosphere 900 m high, that is at the territory of airport.

There is no doubt that both local pollution and regional pollution are very serious issues. It is thought that European Directives on permitted levels aircraft emissions will limit the expansion of some airports.[1]

The major concern associated with all environmental issues of airports is the lack of techniques for impact assessment and existing modeling tools are in general inadequate [2]. However, the existing research and available techniques are focused on the possible larger-scale impacts of aviation, especially climate change, noise pollution and ozone depletion.

But local effects at the area of airport are very often out of research interests. Nevertheless aircraft emissions and related physical process cause a range of negative effects, among which microclimate changes at airport are studied the least, but they are of high importance. They are the product of all major impacts and some specific processes.

EXPERIMENTAL PART AND RESULTS OBTAINED.

Atmosphere structure as a factor of pollution consequences. During flight, aircraft engines emit carbon dioxide, oxides of nitrogen, oxides of sulphur, water vapor, hydrocarbons and particles - the particles consist mainly of sulphate from sulphur oxides, and soot. These emissions alter the chemical composition of the atmosphere in a variety of ways, both directly and indirectly. The impact of aircraft emissions can be very different depending whether they are in the upper troposphere or the lower stratosphere, and that in turn depends on aircraft type.

Subsonic aircraft generally cruise in an altitude range of 9 - 13 km, close to the tropopause, the sharp transition between the troposphere and the stratosphere. The troposphere is the region in which the turbulent motions and precipitation related to weather occur. In contrast the stratosphere is relatively stable and the vertical motions in it are generally sufficiently small compared with the horizontal motions that the air travels almost horizontally.

The height of the troposphere varies with latitude. In the tropics the tropopause is higher than the normal range of subsonic cruise altitudes but in the polar regions it is usually at the lower end of this range. Whether an aircraft cruises in the upper troposphere or the lowermost stratosphere depends on its location, the weather and the time of year. Supersonic aircraft typically cruise at levels in the range 17 - 20 km, which is always in the stratosphere.

The dominant physical and chemical processes differ between the troposphere and stratosphere, as do the time-scales for transporting air between regions. Water vapor added by any human activity in the troposphere is soon lost through mixing and precipitation processes, whereas at 20 km it persists and moves slowly towards the pole.

Formation of cirrus clouds. In the troposphere the amount of water vapor emitted in aircraft exhaust is negligible compared with the pre-existing concentrations in the atmosphere. But stratosphere is almost free of water vapors. Flying aircraft also produces intensive particulate pollution. Due to specificity of air circulation in the stratosphere this dust cloud moves slowly in the horizontal plane. So, when the moist, high temperature air from a jet engine mixes with the ambient cold air, saturation can occur and the moisture can condense onto particles in the atmosphere, and in particular those present in the exhaust. The result is a condensation trail, or contrail [3, 4].

On about 10–15% of occasions in the upper troposphere in middle latitudes, the ambient air is already supersaturated with respect to ice. In supersaturated conditions contrails will persist for hours, tend to spread and perhaps trigger further changes in the atmosphere. Sometimes they can spread to form or initiate a cirrus cloud, though the amount of such cirrus clouds formed by aviation is currently unknown. The extent of the contrail and cirrus cloud can be striking; those detected over the Atlantic occupy thousands of square km.

Contrails and cirrus clouds reflect some solar radiation and therefore act to cool the surface. They also absorb some upwelling thermal radiation, re-emitting it both downwards, which acts to warm the surface, and upwards. On average the latter warming effect is thought to dominate. And on the whole effect of cirrus cloud is in leveling the daily difference in temperature at the airport territory.

Input of aircraft emissions in climate changes on a global and local scale. Microclimate of airport is also affected by other greenhouse gases emitted by aircrafts. These gases change the absorption of solar radiation in the atmosphere and the absorption and emission of thermal radiation of the surface.

Some gasses are considered to be “conservative”, meaning that they become well mixed throughout the atmosphere so that the point of emission is irrelevant for its impact on climate. Carbon dioxide and methane behave as conservative gases. However, oxides of nitrogen, produced by high temperature burning in the engine, are rapidly involved in chemical reactions that lead to changes in both ozone and ambient methane. Ozone is generally produced by oxides of nitrogen in the troposphere and destroyed by it in the lower stratosphere. Since the lifetime of ozone is relatively short, its aircraft-induced increase or decrease is restricted in both the vertical and the horizontal. The lifetime of methane, however, is sufficiently long that the reduction in it produced by the emitted oxides of nitrogen becomes distributed throughout the atmosphere.

But the effect of these gases is opposite and different in scale. Thus, carbon dioxide acts to warm the surface of the Earth globally. The aircraft-induced reduction in the greenhouse gas methane is also well mixed and therefore acts to give a global cooling effect.

However, ozone is also a greenhouse gas and its impact is normally considered in terms of a global warming effect. But its aviation-induced increases remain quite local and impacts on climate from such increases are therefore likely to be more important exactly at the territory of an airport.

To estimate the relative and absolute importance of various emissions on climate, globally averaged measure, known as “radiative forcing” is used to express the imbalance in solar and thermal radiation caused by the sudden addition of any emission. This is a useful concept because models show that the change in globally averaged surface temperature is usually approximately proportional to radiative forcing. According to IPCC, in 1992 aviation was responsible for 2% of carbon dioxide emissions due to the total burning of fossil fuel and 13% of that associated with transport. Since the vast majority of the flights were subsonic and therefore in the 9 - 13 km height range, the emissions of oxides of nitrogen led, on average, to an increase in ozone as well as a decrease in methane. Relative to carbon dioxide, the radiative forcing factors were estimated to be +1.3 for ozone and -0.8 for methane. The impacts of water vapour, and sulphate and soot particles were given as small and positive. The total radiative forcing was calculated to be about 2.7 times that of the carbon dioxide alone, a factor that compares with numbers generally in the range 1 - 1.5 for most other activities. Consequently, aircraft were seen as being responsible for 3.5% of the total radiative forcing in 1992 on a global scale [4, 3].

Local microclimate as it was stated above is also under the influence of cirrus clouds. Contrails were given the radiative forcing factor +1.1. But this value is a subject of extremely large uncertainty, from +0.3 to +3.2 times the impact of the carbon dioxide [3, 4].

It should be noted that a recent comparison of the three-day period following 11 September 2001, when all commercial aircraft in the United States were grounded, has shown some evidence of a 1°C to 2°C increase in the day-night difference in temperature over the USA [4]. This is consistent with the theoretical proposition that aircraft contrails and related cirrus cloud act to lower day-time temperatures by reducing solar radiation and raising night-time temperatures by reducing heat loss. If the result turns out to be robust it will be the first empirical evidence that aircraft contrails and related cirrus cloud are indeed significant in the Earth's radiation balance.

The use of the global radiative forcing concept and the opposite signs of the two oxides of nitrogen-related impacts associated with changes in ozone and methane doesn't imply that the combined effect is unimportant. The well-mixed gases lead to effects, which are almost uniform with latitude and the methane reduction tends to compensate the carbon dioxide increase in the Southern Hemisphere. The radiative imbalance is concentrated in the middle latitudes of the Northern Hemisphere. The contrast between the two hemispheres could have global climate importance and the region with the stronger radiative forcing would be expected to experience larger local climate change [2].

Results of microclimate changes assessment at ukrainian airports. Based on the established regularities of climate changes, presented in a range of IPCC reports the calculation procedure of temperature fluctuations, caused by aviation emissions [3]. The data about volumes of transportation at the following airports were studied: Lviv, Ivano-Frankivsk, Donetsk, Simferopol and Dnipropetrivsk.

The calculation procedure includes calculation of total CO_2 emissions, produced by landing and taking off aircrafts, depending on working parameters of their engines. Then, the final concentration of carbon dioxide in the air of the airport was calculated, supposing that 20-33% of the gas is blown away from the territory of airport and the calculated air volume is limited with the borders of airport to the height of 900 m, which is usually treated as the boundary layer. Using the concentration provided and radiative forcing defined for carbon dioxide the potential temperature increase is calculated in degrees comparing to the background concentration of CO_2 at the airport.

Results for the given airports have showed, that the temperature excess ranges from 0,8 (Ivano-Frankivsk airport) to 2,7 (Dnipropetrivsk) and 4,2 (Donetsk), which is over mitigating ability of the atmosphere.

CONCLUSIONS. The perception of the global warming effect problem shouldn't be restricted to consideration of possible changes in globally averaged surface temperature. However, it should be noted that such a measure of climate change is limited in its scope. Further, the importance of regional and local changes in climate forcing is likely to be particularly underestimated by this global measure. Important aspects of such climate change could be a local change in average precipitation or the frequency and intensity of heat waves, which is of high importance for airports.

Taking into account potential growth of air traffic in the nearest future, the local climate effects could raise increased concerns at scientists and airport management due to the problems with the environment balance at the adjoining territory and local weather fluctuations, complicating airport operations.

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АНАЛИЗ ВЛИЯНИЯ ВОЗДУШНЫХ СУДОВ НА ИЗМЕНЕНИЕ МИКРОКЛИМАТА В ЗОНЕ АЭРОПОРТА

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Проанализированы основные факторы, которые вызывают изменения климата на местном уровне аэропортов. Показано, что последствия загрязнения атмосферы воздушными судами зависят от строения атмосферы и технических условий, необходимых для полетов сверхзвуковой и дозвуковой авиации. Потенциальные влияния на окружающую среду, вызванные авиацией, исследовались на основе концепции радиационного влияния основных загрязнителей, которые обладают способностью влиять на энергетический баланс атмосферы. Рассмотрено влияние типичных парниковых газов, а также специфические последствия их химических превращений, которые приводят к изменению параметров микроклимата территории. Изучены условия образования инверсионных следов воздушных судов и перистых облаков. Установлено, что перистые облака вместе с выбросами углекислого газа играет важную роль в уменьшении перепада температуры на территории аэропорта, приводят к возникновению непредсказуемых погодных явлений и отклонениям в режиме осадков. Представлены результаты оценки повышения температуры для ряда украинских аэропортов.

Ключевые слова: загрязнение воздуха, аэропорт, микроклимат, парниковый эффект, радиационное влияние.