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Carbon Emissions of Civil Airports in China Mainland and Primary Matching with Carbon Storage Sinks

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ABSTRACT

Large airports generate enormous amount of CO_2 due to frequent landings and takeoffs (LTOs) of airplanes and energy consumption. To advance carbon neutrality, the carbon emissions of airports need to be assessed. This paper evaluated the carbon emissions of airports and the contribution of airplanes in the LTO cycle in China Mainland in 2019 before the COVID-19 pandemic, and completed a simple distance matching analysis in the case of direct air carbon capture and sequestration (DACCS) application. It was found that the total CO_2 emissions from airports in China Mainland in 2019 added up to about 153.52 million tons and the CO_2 emissions from LTOs about 16.25 million tons. Approximately 90% of airports are within 5 km of the nearest sequestration sinks.

Keywords: airport, carbon emission, Landing and takeoff (LTO), distance matching

NONMENCLATURE

Abbreviations	
ACI	Airports Council International
DACCS	Direct Air Carbon Capture and Sequestration
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IEA	International Energy Association
LTO	Landing and takeoff

1. INTRODUCTION

Global attention is constantly focused on the issue of climate governance and carbon neutrality. As an important component of global economy, carbon reduction in the aviation industry is urgent. The volume of aviation activity for domestic and international passenger flights increased more than 2.7-fold between 2000 and 2019, while CO_2 emissions from aviation have risen rapidly, reaching nearly 1 billion tons in 2019, about 2.8% of global CO_2 emissions from fossil fuel combustion[1]. Forecast by the International Air Transport Association (IATA), the amount of air transport and the number of new airplanes will continue to increase after the epidemic. Thus, there will be tremendous pressure on the aviation industry to reduce carbon emissions.

China has now become the world's largest carbon emitter. The Statistical Bulletin on the Development of China's Civil Aviation Industry shows that from 2015 to 2019, the average annual growth rate of China's civil aviation fleet size reached 9.6%, while the total transport turnover grew at an average annual rate of 11.0%. The task of carbon reduction in China's civil aviation is facing challenges.

Due to frequent landings and takeoffs (LTOs) of airplanes and huge energy consumption by airports, the concentration of pollutants discharged on the ground is quite high. While airport carbon emissions mainly come from indirect energy consumption of electricity and heat. Therefore, large busy airports can be good places to apply carbon-reduction technologies.

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Most current studies focus on the calculation of carbon emissions from the standard LTO cycle of airplanes. Chen L[2], Dissanayaka[3] et al. calculated carbon emissions of airlines in accordance with the International Civil Aviation Organization (ICAO) standards.

The calculation of the airport's carbon emissions is complex and involves many models and energy efficiency indices. Airports Council International (ACI) has developed an Airport Carbon and Emissions Reporting Tool (ACERT)[4] for airport operators to estimate the greenhouse gas emissions by inputting readily available operational data, and guided them to adopt emissions reduction measures.

This paper calculated the carbon emissions of each airport and the contribution of airplanes in the LTO cycle based on 2019 Civil Airports Production Statistics Bulletin issued by the Ministry of Transport of the People's Republic of China, and completed a simple distance matching analysis in the case of direct air carbon capture and sequestration (DACCS) application.

2. METHODS

2.1. Calculation of carbon emissions in the LTO cycle of an airplane

The LTO cycle is the process of the aircraft landing at high altitude to the airport and taking off from the airport to high altitude. ICAO specifies that a standard LT0 phase consists of four flight modes: taxi, takeoff, climb and approach.

The formula to calculate CO_2 emissions in phase LT0 is as follows[2].

$$E = n \times f \times e \qquad (1)$$

Where, E is the $C0_2$ emission of LT0 phase, kg. n is the number of engines in one airplane. f is the single-engine fuel flow in LTO cycle, kg, referred from ICAO Aircraft Engine Emissions Databank[5]. e is the fuel C02 emission index, set to 3.15 $kgCO_2/kg$.

By the end of 2019, there were 3,893 domestic airplanes operating under Civil Aviation Regulation of China Part 121 (CCAR-121), with 8,143 engines in use[6]. Among the engines, CFM56-7B, CFM56-5B and V2500 have the highest percentage at 35.74%, 20.41% and 15.66% respectively[6]. Each series of the engines has different models. CFM56-7B, for example, comprises CFM56-7B18, CFM56-7B20, CFM56-7B24, CFM56-7B27, etc. Without access to detailed data of domestic airplanes and engines, the average value of LTO fuel of various models of CFM56-7B series from ICAO Aircraft Engine Emissions Databank was chosen as the LTO fuel of CFM56-7B series engines. The result is indicated in table 1.

Table 1 Fuel in LTO cycle

Engine Series	Fuel in LTO Cycle (kg)
CFM56-7B	413
CFM56-5B	426
V2500	442

Assuming all engines are composed exclusively of three series of CFM56-7B, CFM56-5B and V2500 proportionally, we calculated that one LTO cycle requires 884.62 kg of fuel and produces 2,786.54 kg of CO_2 emissions.

2.2. Airport carbon emission measurement model

The latest version of ACERT v6.0 divided carbon emissions from airports into three categories in terms of the ownership and control of the emission sources: 1. Airport direct carbon emissions owned or controlled by the airport authority, including direct emissions from the operation of power stations and various safeguard vehicles owned by the airport party; 2. Airport indirect carbon emissions from electricity and heat purchased by the airport from the municipal grid; 3. Other indirect carbon emissions owned or controlled by other resident units, including emissions from airplanes operating in the airport area, vehicles by airlines and other resident units, ground support equipment and electricity emissions, and ground vehicles for passengers and staff to and from the airport. Using the single factor correlation method, Li J[7] analyzed the relationship between passenger throughput and CO_2 emissions. It is found that the total passenger throughput of 16 airports in China from 2009 to 2013 is highly positively correlated with the total CO_2 emissions, where the correlation coefficient is 0.99. Therefore, this paper used passenger throughput to analyze and predict the CO_2 emission at the airport.

$$y = 0.0239x + 507158.4808 \qquad (2)$$

Where, x is airport passenger throughput, and y is airport carbon emissions in ton.

3. RESULTS AND DISCUSSION

3.1. Carbon Emissions of Civil Airports in China Mainland in 2019

The distribution of civil airports and their CO_2 emissions in China Mainland in 2019 are illustrated in Figure 1. There were 39 airports with an annual passenger throughput of over 10 million, accounting for 83.3% of the overall passenger throughput of domestic airports. The passenger throughput of Beijing, Shanghai and Guangzhou airports accounted for 22.4% of the

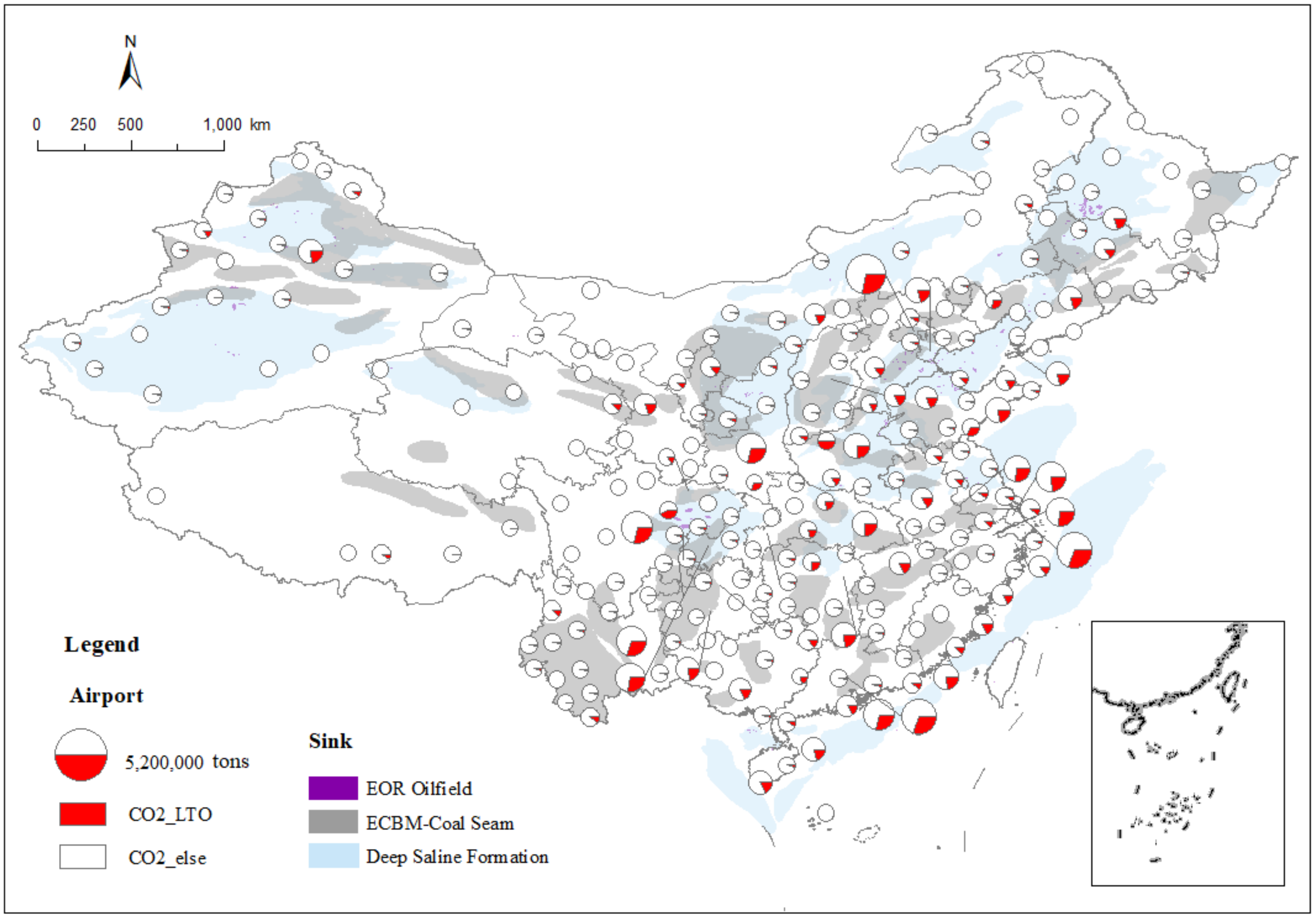

Fig. 1 CO_2 Emission of Civil Airports in China Mainland in 2019

total. North China, East China, Central-South China and Southwest China were the regions with the largest passenger throughput in China, accounting for 84.4% of the total. Responsively, the total CO_2 emissions from airports in China Mainland in 2019 amounted to about 153.52 million tons, while the CO_2 emissions from LTO approximately 16.25 million tons. Airports with a throughput of 10 million or above had CO_2 emissions of about 46.7 million tons, or 30%, while airplanes in LTO have CO_2 emissions of about 11.05 million tons, or 68%. There were 5 airports with a passenger throughput of over 50 million. The CO_2 emissions in those airports and the contribution of airplanes during LTO are indicated in Table 2.

Table 2 CO_2 emissions in airports with a passenger throughput of over 50,000,000

Airport	throughput	LTO cycle	CO_2_ACERT (ton)	CO_2_LTO (ton)
PEK	100,013,642	594,329	2,897,484.52	828,048.88
PVG	76,153,455	511,846	2,327,226.06	713,129.44
CAN	73,378,475	491,249	2,260,904.03	684,432.67
CTU	55,858,552	366,887	1,842,177.87	511,165.31
SZX	52,931,925	370,180	1,772,231.49	515,753.29

As shown in Table 3, East China, Central-South China, Southwest China and North China had high CO_2 emissions in airports, due to the large passenger throughput and frequent airplanes LTO. Those are the areas to be preferred by future application of emission reduction technologies.

Table 3 CO_2 emissions from airports in China Mainland by region

Region	throughput	LTO cycle	CO_2_ACERT (ton)	CO_2_LTO (ton)
Northeast China	83,408,135	371,229	15,179,575	1,034,428
North China	194,750,289	776,614	23,419,396	2,164,034
East China	398,459,771	1,589,625	31,838,162	4,429,489
Northwest China	88,687,437	447,964	14,291,433	1,248,252
Southwest China	219,238,220	950,520	30,090,559	2,648,625
Xinjiang Region	37,584,606	222,820	11,548,600	620,889
Central-South China	329,500,087	1,471,466	27,147,074	4,100,240
SUM	1,351,628,545	5,830,238	153,514,799	16,245,957

3.2. Primary Matching of airports with CO_2 Storage Sinks

To achieve carbon neutrality in China in the future, the CO_2 emissions from airports must be addressed. Each airport can be seen as a large carbon source. Due to the high concentration of CO_2 around the airport, there is an opportunity to implement the DACCS technology. The data of geological sequestration sinks in China Mainland are obtained from ChinaCCS decision support system[8]. As shown in Figure 1, airports in most provinces and cities can be found matching geological sequestration sinks within a reasonable distance except for Tibet, Sichuan and Gansu. Hence the distances from each airport to its adjacent sequestration sink can be obtained based on the distribution of airports and potential geological sequestration sinks. As shown in Figure 2, 213 airports out of 239 airports are within 5 km from the sequestration sink; 139 less than 3 km, 85 less than 2 km and 29 less than 1 km. Southwest China, East China, Central-South China, and North China have preferable source-sink matching. The deep saline formations are widely distributed and have a good matching with civil airports in the implementation of DACCS.

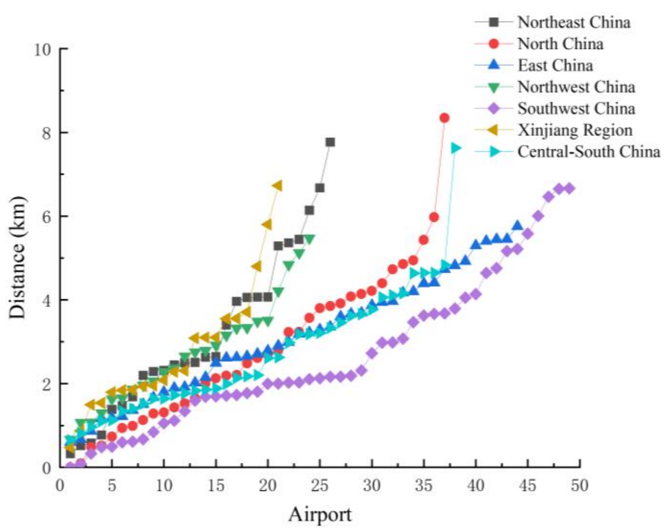

Fig. 2 Distance Curve of Each Airport to its Adjacent Storage Sink

4. CONCLUSIONS

This paper estimated the carbon emissions in airports in China mainland in 2019. It was found that the total CO_2 emissions from airports in China Mainland in 2019 added up to about 153.52 million tons and the CO_2 emissions from LTOs about 16.25 million tons. Since the two models used to calculate CO_2 emissions in this paper were from ICAO and ACI respectively, there would be inconsistencies in settings and assumptions. In addition, the data of the engine type and number, LTO fuel quantity, etc. were based on theoretical derivation, and the averaging simplification process was performed, which would produce some errors on the results. To obtain more accurate results, a corresponding database needs to be established. For airplanes, it is necessary to obtain information including the time, engine type and quantity of each stage of aircraft LTO, and then calculate directly with data from quick access recorder. For airports, Internet of Things and big data should be applied to finely coordinate airport departments and traffic equipment.

This paper probed just a preliminary matching of airports and CO_2 storage sinks in terms of distance. Approximately 90% of airports are within 5 km of the nearest sequestration sinks. East China, Central-South China, Southwest China and North China are the areas preferred by future application of emission reduction technologies. The layout of the DACCS pipeline network taking into account the economic feasibility will be further researched in the future. Moreover, the choice of carbon reduction technologies for airports will be studied in depth.

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