Greenhouse Gas Pollution in the Stratosphere Due to Increasing Airplane Traffic, Effects On the Environment

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Abstract

The puzzle of climate is that atmospheric and oceanic temperatures have increased much more than can be explained by changes in the concentration of greenhouse gases. We suggest that part of the reason for this phenomenon maybe the increasing volume of jet airline traffic round the clock and around the globe which is contributing to higher concentrations of greenhouse gases in the stratosphere than in the whole atmosphere. This indicates that the increasing volumes of airplane traffic worldwide have serious environmental consequences, perhaps more serious than the ozone hole phenomenon on which the attention of the scientific community is riveted.

Key words: Plane travel, greenhouse gases, stratosphere, atmosphere, atmospheric and oceanic temperatures, ozone hole phenomenon.

The Emergence of the Airplane As the Primary Vehicle for Long Distance Travel

Technological developments have resulted in many changes in the most popular mode of travel over the last 200 years. In this period, the primary vehicle for long distance travel has changed first from horse drawn carriage to the railways, then from the railways to the private automobile, and finally from the private automobile to the airplane. Because of its convenience and speed, today the airplane has become the most commonly used vehicle by most people for trips longer than a few hundred miles.

Rapid increase in human population, increasing urbanization and dispersal of each ethnic group over widely separated geographic regions, are contributing to a steep growth in the demand for plane travel. This growth rate is high in developed countries, and somewhat lower in developing countries.

This growth in the demand for plane travel in turn is leading to tremondous increases in the construction of huge airport facilities, in the development of large jumbo and superjumbo jet airplanes, and ultimately in the number of flights taking off daily from airports. As an example, the number of spaces for parked cars at the Detroit Metropolitan Airport near where I live has increased by a factor of over 10 in the thirty year span between 1970 to 2000, and yet, quite often passengers are unable to get a parking space at this airport. Also, at almost all major airports in developed countries, there is usually a plane taking off or landing every 10 seconds round the clock.

Also, wealthy developed countries logon a large number of flying hours on the huge numbers of their military aircraft for spying on other countries and for keeping the flying skills of their bomber pilots sharp.

For convenience in presenting my arguments let me introduce some notation here.

$p =$ percentage of greenhouse gases (CO_2 and others) in the whole atmosphere

$p_e =$ percentage of greenhouse gases at the upper edge of the atmosphere (altitude of 40,000 feet above sea level) where the atmospheric pressure of 9 m.b. is less than 1% of the atmospheric pressure of 1013 m.b. at sea level, so the air there is highly rarefied.

The combustion of fossil fuels in various human activities is leading to a steady increase in the value of p, this is expected to cause an increase in atmospheric and oceanic temperatures. However, in recent years scientists have observed much higher rates of increase in these temperatures than what can be explained by the moderate increase taking place in the value of p. For example the report in [1] states

> "... it is by no means clear how an increase of less than 1 percent per year in atmospheric greenhouse gases such as carbon dioxide (CO_2) could possibly cause extra warming to raise sea surface temperatures by 0.1 degree per year. "Most likely it reflects a combination of several different factors in a complex relationship that is not yet understood" said Gregory Withee, NOAA assistant administrator for satellite and information services..."

This phenomenon has been perplexing. See also [2]. In [3] it has been reported that in August 2000, for the first time in 50 million years, the north pole is awash in water because the thick ice that has for ages covered the Arctic Ocean at the pole has turned to water. The report says that an ice-free patch of ocean about a mile wide has opened at the top of the world, this same area was observed six years ago to have been covered by a layer of ice at least nine feet thick. This report concludes that the rate of atmospheric and oceanic warming has accelerated significantly in the last quarter century. In [4] it is reported that ocean temperatures in the tropical northern hemisphere are going upwards by 10 times the global average, due to which there is a very high probability that coral reefs as we know them now will be gone in 30 to 50 years.

Atmospheric Mixing

When some external material is introduced in a region of the atmosphere, atmospheric mixing and dispersion tend to make the composition of air uniform all over the atmosphere, if given enough quiet time to settle down.

What Is Increasing Plane Travel Doing to the Composition Of Air in the upper Edge Of the Atmosphere?

Modern jet planes fly in the upper edge of the atmosphere for minimizing fuel consumption. Since the air in this region is so rarefied, its local momentary composition changes easily even with the introduction of moderate quantities of external materials. A flying jet plane spews large quantities of greenhouse gases all along its flight path in its exhausts.

CO_2, the main constituent in the exhaust gases, is heavier than air, its density relative to that of air is 1.53. Its freezing point is -56.6^{0c}. At the altitude of 40,000 feet above sea level where commercial jetflights operate, the outside air temperature varies between -35^{0c} to -50^{0c}, slightly warmer than the freezing point of CO_2. However, since the vapor pressure of CO_2 at -50^{0c} is 101 psig, the CO_2 released in jet airplane exhausts at an altitude of 40,000 feet will not condense, instead it will disperse in the air at that altitude, and may gradually descend to lower altitudes very slowly, taking several years (see page 30 in [5]). Factors contributing to the slowness of descent of these gases to lower altitudes are: the fact that the region where they are released is well above the altitude from where precipitation of water and snow to ground level takes place, and the temperature inversion at the troposphere-stratosphere boundary.

The large number of modern jet planes flying and spewing greenhouse gases, and the rarefied nature of air in this region have resulted in significant increases in the value of p_e. Since plane traffic continues round the clock, the value of p_e never gets a chance through atmospheric mixing to settle down to the value of p. Because of this, there is serious greenhouse gas pollution in the upper edge of the atmosphere; i.e., a permanent increase in the value of p_e well above the value of p. A greenhouse gas envelope at the stratospheric level is much more effective than one at a much lower altitude, at blocking radiant energy from escaping the earth. Thus a higher value of p_e than p may explain the perplexing phenomenon of substantially higher rates of increase in the atmospheric and oceanic temperatures.

Comparing the Fuel Consumption Rates of Commercial Jet Airplanes and Commercial Ground Vehicles

We will now compare the fuel consumption rates of commercial jet airplanes, and public transport ground vehicles like buses. Airline data [6] for this comparison has been obtained courtesy of Northwest Airlines inc. For a fair comparison, we will assume a constant occupancy rate of 80% for both vehicles. In the airline industry, the average occupancy rate is about 80%.

A modern jet airplane like the Boeing 747-200 burns approximately 29,000 gallons of aviation fuel on a flight from Minneapolis to Amsterdam, a ground distance of about 3750 miles. The average number of passenger seats in a Boeing 747-200 is about 350, so under the assumption of 80% occupancy, it carries 280 passengers. These facts imply that the fuel consumption rate of this jet on this route is $(29{,}000)/(280 \times 3750) = 0.02762$ gallons/paseenger mile. The same plane on a flight from Detroit to Los Angeles burns approximately 16,045 gallons of aviation fuel for a ground distance of 2276 miles. So, the fuel consumption rate of this jet on this route is $(16{,}045)/(280 \times 2276) = 0.0252$ gallons/passenger mile. From the data on these two routes we conclude that the fuel consumption rate of this jet is slightly over 0.025 gallons/passenger mile.

To get comparable fuel consumption data for public ground vehicle transportation systems, I approached the University of Michigan, Ann Arbor (UM), Bus Service connecting the various campus areas (Central Campus, North Campus, and the various Student Housing, and Parking areas), operated by the university for the convenience of students and other members of the university community. Fuel consumption data for this system has been provided by the UM Office of Parking and Transportation Services [7]. An average bus in this system consumes 3545.5 gallons of gasoline for delivering 15680 service miles per year, which works out to $15680/3454.5 = 4.54$ sevice miles/gallon. The rated capacity of the bus is 80 passengers (even though during peak travel periods the buses may carry upto 100 passengers in them), and during daytime hours 80% occupancy on an average is typical. At 80% occupancy rate the bus will have $80 \times 0.8 = 64$ passengers in it. So, the fuel consumption rate of this bus is $1/(64 \times 4.54) = 0.00344$ gallons/passenger mile. A well-run commercial bus service can be expected to have a comparable fuel consumption rate.

From these figures we see that the fuel consumption rate of the commercial jet airplane is $0.025/0.00344 = 7.3$ times that of a comparable ground vehicle (a bus in a public bus system).

Even though an average automobile has five seats, in normal use in USA, the occupancy rates in private automobiles on the road is very low (estimated to be an average of 1.2 passengers including the driver). Of course it would not be fair to compare the fuel consumption rate of a commercial jet airplane directly with that of a privately owned automobile. But, for the sake of comparison, we will calculate the fuel consumption rate of an automobile per passenger mile under the assumption of 80% occupancy, the same as in the commercial jet airplane. At 80% occupancy, an automobile carries 4 passengers, and typically gets about 25 miles/gallon on the highway. So, the fuel consumption rate of the automobile under the 80% occupancy assumption is $1/(25 \times 4) = 0.01$ gallons/passenger mile.

These facts are summarized in the following table.

Vehicle	Fuel consumption rate	Fuel consumption rating/passenger mile compared to a bus*
Jet airplane	7.75 gallons/mile	7.3
Bus	4.54miles/gallon	1
Private automobile	25 miles/gallon	2.9

*Ratio of fuel consumption/passenger mile of vehicle and of the bus, all computed under the assumption of 80% occupancy rate which is typical for commercial airplanes and buses.

Ground vehicles release greenhouse gases at ground level where the air density is high. A modern jet airplane not only burns many times the fuel burnt by the ground vehicles per passenger mile, it releases its exhaust gases in the fragile and rarefied region of the stratosphere where the air density is only 1% of that at ground level.

Relationship to the Ozone Hole Phenomenon

The controversy of the ozone holes over the polar regions has captured the attention of the scientific community in the last 20 years. In this controversy, it is believed that organo-halogen compounds released at ground level migrate to the polar regions in the stratosphere, stay there and destroy the ozone layer in that region. At present this ozone hole phenomenon is the focus of a large number of investigations.

Modern jet airplane traffic is releasing large quantities of the other major air pollutant, greenhouse gases, directly into the stratosphere. And yet, so far no one has paid any attention to the environmental effects of this activity.

The Environmental Impacts of Increasing Jet Airplane Traffic

Jet airplane traffic is going up at a heady rate worldwide these days [8]. Because this traffic is releasing large quantities of greenhouse gases into the stratosphere directly, around the globe and round the clock, this traffic is perhaps the major contributor to the observed global warming. The report in [4] states that ocean warming is the most menacing threat contributing to the expected total destruction of coral reefs all around the world in the next 50 years. The article [9] examines the serious consequences that global warming poses to human health around the world. And yet, the very serious environmental consequences of increasing airplane traffic have not so far been recognized by the scientific community, or grabbed the attention of the general public.

I believe that it is high time that we realize the serious environmental impacts of increasing airplane traffic, and discuss widely whether anything can be done to make sure that it does not become a major crisis.

Acknowledgemets

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