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

Katta G. Murty

Department of Industrial and Operations Engineering
University of Michigan, Ann Arbor, Michigan 48109–2117, USA
Phone: 734-763-3513; fax: 734-764-3451; e-mail: katta_murty@umich.edu
webpages: http://www-personal.engin.umich.edu/~murty/
http://www.guthy.com/murty/index.html

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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 may be 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 tremendous increases in the construction of huge airport facilities, 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 has increased by a factor of over 10 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 log 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.

We introduce some notation.

$p =$ % of greenhouse gases ($CO_2$ and $NO_x$) in the whole atmosphere
$p_e =$ % of these greenhouse gases in bottom portion of stratosphere where jet airplanes fly (about 40,000 feet above sea level).

The combustion of fossil fuels in various human activities is leading to a steady increase in the value of $p$, which 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 "Waters Near Equator Show Alarming Warming Trend" in Washington Post, 29 July 2000 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. In "North Pole is Watery, Warmer" in Detroit Free Press, 22 August 2000, 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 "A Growing Coral Crisis: Overfishing and Global Warming Are Killing Reefs Around the World. Is it Too Late to Save Them?", Newsweek, 30 October 2000, 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 Stratosphere?

Modern jet planes fly in the bottom portion of the stratosphere, where the atmospheric pressure is 9 m.b., which is less than 1% of the atmospheric pressure of 1013 m.b. at sea level, to minimize 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 ($CO_2$ and $NO_x$) 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, freezing point is $-56.6^{0c}$. At the altitude where commercial jets fly, 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 will not condense, instead it will disperse at that altitude, and may gradually descend to lower altitudes very slowly, taking several years (see page 30 in [1]). 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 there is no vegetation to absorb $CO_2$ there, and the temperature inversion at the troposphere-stratosphere boundary.

The large number of modern jet planes flying 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 $p$, resulting in 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, it 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 fuel consumption data obtained courtesy of Northwest Airlines Inc. (I thank Andrea Fischer Newman, VP, Northwest Airlines, for her efforts in getting this data) is given below.

Boeing 747-200 Fuel Consumption Data

| Route | Ground distance | Average fuel consumption |
|---|---|---|
| Minneapolis - Amsterdam | 6035 km | 109,774 liters |
| Detroit - Los Angeles | 3663 km | 60,735 liters |
| Capacity = 350 seats, Average occupancy = 80% | | |

Fuel consumption data for ground vehicles (buses) in a public transportation system obtained from the Campus Bus Service, University of Michigan, Ann Arbor (I thank their Office of Parking and Transportation Services for this data) is given below.

Annual average fuel consumption per bus = 13421 liters
Annual average service distance per bus = 25234 km
Rated capacity of bus = 80 passengers
Average occupancy rate = about 80%

Even though an average private automobile has five seats, in normal use in USA, its occupancy rate 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 rates of a commercial jet airplane or a public bus directly with that of a privately owned automobile. But, for the sake of comparison, we will calculate the fuel consumption rate of a private automobile per passenger mile under the assumption of 80% occupancy, the same as in the commercial jet airplane, and public buses.

The results are summarized in the following table.

Fuel Consumption Comparisons

| Vehicle | Fuel consumption rate | Fuel consumption rating/passenger mile compared to a bus* |
|---|---|---|
| Boeing 747-200 | 17.5 liters/km | 7.9 |
| Public Bus | 1.9 km/liter | 1 |
| Private automobile | 10.6 km/liter | 3 |

*Ratio of fuel consumption/passenger km of vehicle and bus, under assumption of 80% occupancy, typical in commercial airplanes & buses.

Ground vehicles release greenhouse gases at ground level where the air density is high, and there is growing vegetation to absorb at least some of the $CO_2$ in it. A modern jet airplane not only burns many times the fuel burnt by the ground vehicles per passenger km, it also 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 pollutants, 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

As reported in CBS News 60 Minutes on 26 November 2000, jet airplane traffic is going up at a heady rate worldwide these days. 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 Newsweek cited earlier 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 [2] 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.

## References

[1.] T. E. Graedel and P. J. Crytzen, *Atmosphere, Climate, and Change*, Scientific American Library, 1995.

[2.] P. R. Epstein, "Is Global Warming Harmful to Health", *Scientific American*, August 2000, 283, No. 2, pages 50-57.