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# CASE ORANGE

## CONTRAIL SCIENCE, ITS IMPACT ON CLIMATE AND WEATHER MANIPULATION PROGRAMS CONDUCTED BY THE UNITED STATES AND ITS ALLIES

**Compiled for the Belfort Group,**

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If we can stand up to them, all Europe may be free and the life of the world may move forward into broad, sunlit uplands. But if we fail, then the whole world, including the United States, including all that we have known and cared for, will sink into the abyss of a new Dark Age made more sinister, and perhaps more protracted, by the lights of perverted science.

Winston Churchill, 'This was their finest hour' speech to the House of Commons, June 18th 1940.

**CONTENTS:**

Appendix 17 Annonce de la sale d'acquisition dématerialisée (order form screenshots).

Appendix 18 Top economists recommend climate engineering (article).

Appendix 19 Modification of Cirrus clouds to reduce global warming (survey).

Appendix 20 List of U.S. secrecy orders (official document) – example of a secrecy order (official document).

Appendix 21 H.R. 2977: space preservation act of 2001 (official document).

Appendix 22 Top-down planet hackers call for bottom-up governance (article).

Appendix 23 Rapports d'analyse (chemical analysis).

Appendix 24 Aerotoxic syndrome: a descriptive epidemiological survey of aircrews exposed to in-cabin airborne contaminants (survey).

Appendix 25 Jet fuels JP-4 and JP-7 health effects (survey).

## LIST OF ABBREVIATIONS:

| | |
|---|---|
| AFB | Air Force Base |
| ATP | Airline Transportation Pilot |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| AWACS | Airborne Early Warning and Control System |
| BKN | Broken clouds |
| °C | Degrees Celsius |
| Ci | Cirrus |
| Cc | Cirrocumulus |
| CO | Carbon Monoxide |
| DLR | Deutsches Institut für Raumfahrt |
| DOD | Department of Defense |
| DTR | Diurnal Temperature Range |
| ECM | Electronic Counter Measures |
| ELF | Extreme Low Frequency |
| EPA | Environmental Protection Agency |
| FAA | Federal Aviation Administration |
| FIR | Flight Information Region |
| ft | Feet |
| GWP | Global Warming Potential |
| HAARP | High Frequency Active Auroral Research Program |
| HC | Hydrocarbons |
| HMSO | Her Majesty's Stationary Office |
| Hz | Herz |
| ICAO | International Civil Aviation Organization |
| IPCC | International panel for Climate Change |
| Kg | Kilogram |
| KW | Kilowatt |
| Lbs | Pounds |
| NASA | National Air and Space Agency |
| NATO | North Atlantic Treaty Organization |
| SALT | Strategic Arms Limitations Talks |
| Sct | Scattered clouds |
| SN | Smoke Number |
| SOP | Standard Operating Procedure |
| UEA | University of East Anglia |
| UIR | Upper Information Region |

| | |
|---|---|
| USSR | Union of the Socialist Soviet Republics |
| VLF | Very Low Frequency |
| WMO | World Meteorological Order |

# 1. EXECUTIVE SUMMARY

## 1. EXECUTIVE SUMMARY:

This unclassified research paper has been compiled on request of the Belfort Group, a Belgian environmental watchdog. It highlights the specific problems associated with contrails emitted by aircraft, the manipulation for geo-engineering or defense purposes of some of these trails by the United States government and the subsequent effect on quality of life. In order to force public debate on the subject this document has not only been transmitted to embassies of states that organize weather manipulations projects, news agencies and interest groups in this field but also to organizations in countries that are not considered as allied forces by the United States and NATO.

Contrails are not the harmless emissions of aircraft at high altitude that only have an esthetic impact on the sky as meteorologists suggest. They do not only contain huge amounts of water vapor, but also significant amounts of Carbon Dioxide, Nitric Oxide, Sulfur Oxide and soot that have a significant impact on public health. In that respect it is noteworthy that derogations for emissions of Hydrocarbons and Carbon Monoxide have been granted for engines of some military aircraft, which exceed civil regulatory levels in a very significant way. Chapter 3 contains a detailed description how contrails are formed, its detailed chemical composition plus a very interesting case study of the KC135 tanker & E-3 Sentry (AWACS) aircraft, the latter being operated on a Luxemburg registration without complying to civil standards.

Persistent contrails have a devastating impact on eco-systems on Earth. They develop in men made Cirrus cloud that can cover a significant part of the sky. It is scientific evidence that those aviation-induced clouds already occupy 3 to 5% of the sky in Europe and this figure increases by 1 to 2% per decade. As these types of clouds are not classified as such by the WMO, the World Meteorological Organization, there is obviously no tendency to research this subject thoroughly and subsequently civil aviation authorities and other government bodies write the thesis of 'chemtrails' off as a hoax. Nevertheless it is proven that the existence of these persistent contrails has a negative impact on temperature and they can alter precipitations levels. It also induces the dehydration of the stratosphere. Chapter 4 provides a summary of the most striking results of scientific research on this subject.

Given the extensive history record of weather manipulation projects, conducted mainly by the United States armed forces, the relationship between men made contrails and its impact on different climatologic parameters creates a scientific basis for a weather manipulation system. Chapter 5 contains a detailed overview of the major weather modification operations in human history, starting from relatively innocent endeavors such as cloud seeding with silver iodide over ionospheric heating to large-scale geo-engineering projects through commercial aviation. Patents, previously classified documents, order forms for Barium and maps with daily spraying schemes irrevocable denote the existence of a global military sponsored and governmental approved project for alteration of the upper troposphere for global control purposes. The technical details, including the nature of the seeding material and its possible impact on public health, are also included in chapter 5.

Finally the investigation group, which wants to remain anonymous until further notice, comes to the final conclusion that atmospheric seeding for the sake of military interests and a global business model has a devastating impact on eco-systems on this planet and quality of life in general. This practice is therefore considered as unacceptable.

# 2. NOMENCLATURA

Give me a long enough lever and a place to stand on and I will move the earth.

Archimedes (287 – 212 B.C.)

## 2. NOMENCLATURA:

A distinction is made between contrails, distrails, wingtip vortices and 'chemtrails'. In this research paper only contrails and chemtrails are subject to an in-depth study.

### 2.1. CONTRAILS:

**Contrail** is the contraction of the words 'condensation' and 'trail', the condensation of engine exhausts. The word dates back to World War II and contrails were considered as a nuisance as they attracted enemy fighters in the fray.

B-17 heavy bombers are on their way to Schweinfurt, emitting substantial amounts of contrails. German pilots could easily pick out the exact position of individual planes by their contrails.[1]

In contrary to popular belief contrails are not exclusively formed by jet aircraft, but also by propeller driven airplanes, providing that their operating altitude is suitable for their formation. This phenomenon is temperature related. As temperature drops with 2°C/1000 ft altitude gain in a standard atmosphere and a cold air parcel can only hold very limited water vapor any hot exhaust fumes automatically condense into artificial clouds. This usually happens above 26,000 ft where the ambient temperature is below -40°C.

As can be noticed on the picture above the intensity of the contrails vary with altitude / temperature, the bombers on the top right emitting heavier contrails than the planes at the bottom. A very important feature is that these early contrails are short lived. However modern jet aircraft with more powerful engines and high turbine temperatures emit more persistent contrails, which usually 'trail' for 20-30 miles along.

Contrails from a Quantas Boeing 747, Australia (Source: Wikipedia, contrails)

[1] Air & Space Power Chronicles, Schweinfurt – the battle within the battle for the 8th US Air Force, Capt. D. Reichert, USAF

Contrails may have strange shapes and even be horizontally dispersed over large areas by jet streams, strong winds in the upper atmosphere that exceed a velocity of 100 knots.

## 2.2. DISTRAILS:

A distrail is the abbreviation for 'dissipation trail'. When an aircraft passes through a thin, stable cloud, even when the conditions for the production of contrails are not met, it produces a tunnel like path through that cloud.

Distrails are created as a result of the elevated temperature of the exhaust gases absorbing the moisture from the cloud. Clouds exist where the relative humidity is 100% and temperature and dew point are thus equal, but by increasing the temperature, the air can hold more moisture, so the relative humidity drops below 100% even for the same absolute moisture density, thus causing the visible water droplets in the cloud to be converted back into water vapor.

This picture shows a contrail that changes into a distrail at the top right, cutting through a layer of Altocumulus clouds.[2]

## 2.3. WINGTIP VORTICES:

Airplanes fly as a result of an equilibrium of lift, drag, mass and thrust. When a wing generates lift it causes a vortex to form at the wingtips and sometimes also at the trailing edges of the wing flaps. It causes wake turbulence, which is quite persistent and potentially dangerous to other, mostly smaller planes. The higher the angle of attack of the wing the higher the lift coefficient will be with stronger vortices in the end. High angles of attack in commercial aviation are achieved in landing configuration (flaps & landing gear down) or during initial climb after take off (high thrust & body angle).

The reduction in pressure and temperature across each vortex can cause water to condense and make the cores of these wingtip vortices visible. The effect is more common on humid days and in anticyclones with strong temperature inversions. These visible cores contrast with contrails and distrails, the latter being produced directly behind the engine at higher altitude.

Military aircraft travelling at transonic speed and making high performance maneuvers may produce a vapor cone or Prandtl-Glauert singularity as a result of a sudden drop in air pressure, sometimes nicknamed the shock collar or 'shock egg'.

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[2] Contrail science Home Page, http://contrailscience.com/contrail-to-distrail/

A U.S. Air Force F-22 'Raptor' executes a supersonic flyby at low altitude, producing pronounced wingtip vortices and a 'shock egg'.[3]

## 2.4. 'CHEMTRAILS':

Chemtrail is the contraction of 'chemical trail' and is used by some sources to denote intentional spraying by airplanes for military or political purposes and that may be harmful to public health. A more general name is 'aviation smog', which combines contrails, distrails and 'chemtrails'. Authors referring to chemtrails claim that this phenomena is much more persistent than contrails and when sprayed in a grid it is able to cover vast area's.

Although officially denied by government sources many countries performed tests for 'cloud seeding' to either generate precipitation where it was needed or to prevent precipitation where it is unwanted. At this moment only the Russian and Chinese governments admit that they use particular matter in order to manipulate weather patterns.[4]

This picture shows an interesting combination of contrails (right hand side), distrails (bottom left) and possibly 'chemtrails' (left hand side) over Belgium in the vicinity of Brussels, September 2009. Note that the contrails have spread over a large area.

[3] Live Science, Britt R.R., Editorial Director, June 30th 2009, Picture by courtesy of DOD/Petty Officer 1st Class Dejarnett, U.S. Navy.
[4] Michaels Jay, Meteorology News, 19th October 2009, 'Moscow testing cloud seeding'

# 3. CHARACTERISTICS OF CONTRAILS

The intuitive spirit is a gift from God. The rational brain is its servant. We have created a society that worships the servant and has forgotten the gift.

Albert Einstein (1879 – 1955)

## 3. CHARACTERISTICS OF CONTRAILS:

### 3.1. PREVIOUS SURVEYS ABOUT CONTRAILS:

Meteorologists ignore and even deny the effects of aviation on the weather, stating that contrails and in a lesser extend distrails only have an esthetic influence on the way the sky looks. As they do not induce precipitation nor reduce the visibility or affect sunshine they are not worth mentioning in a weather bulletin. On a few occasions meteorologists refer to it as veil shaped clouds, actually making the public belief that its origin is natural and not human. Because contrails are not considered as a weather phenomenon there are subsequently very few scientific surveys covering this topic.

Appleman was the first in 1953 to present charts that forecast the likelihood of contrail formation based upon the temperature profile of the 700–100-Hectopascal layer where commercial jets usually operate. [5] Pilie and Jiusto in 1958[6], Scorer and Davenport in 1970 [7] and Hanson & Hanson in 1995[8] modified his work. They identified a unique range within which a contrail should theoretically form.

However, the lack of field tests to verify these models and the fact that contrails have been noted to form and spread during conditions deemed unfavorable according to some of the models described above. With the introduction of new technology, such as satellites, more accurate surveys were within reach. This resulted for instance in the development of a new empiric model developed by Travis to predict widespread occurrences of contrails [9].

But even with the aid of geostationary satellites it proves extremely difficult to predict formation, size and life span of contrails that may remain isolated or cluster in groups. Extensive survey is mandatory in order to understand fully the nature of contrails. However there is an economic drawback to this, as aviation is the backbone of fast transport and commerce spanning the globe. Any survey can potentially be turned down by lobby groups that do not want to see unwanted attention unleashed on an ignorant public with undesirable side effects of aviation. Officially science does not work that way, but in practice researchers generally do not bite the hand that feeds them. This is also why contrails are politely classified as veil clouds.
Travis D.J, Carleton A.M. and Lauritsen R.G. performed a very interesting survey immediately after the 9-11 attacks in 2001, when all commercial aviation was stuck on the ground for a period of 3 days. It was probably the only opportunity to perform a comparative study. The results were only released two years later and proved the evidence of jet contrail influence on climate,[10] although it was suggested by some other researches that 'the sky was unusually clear during that period'.[11]

The results of some of these surveys are used in the next paragraphs.

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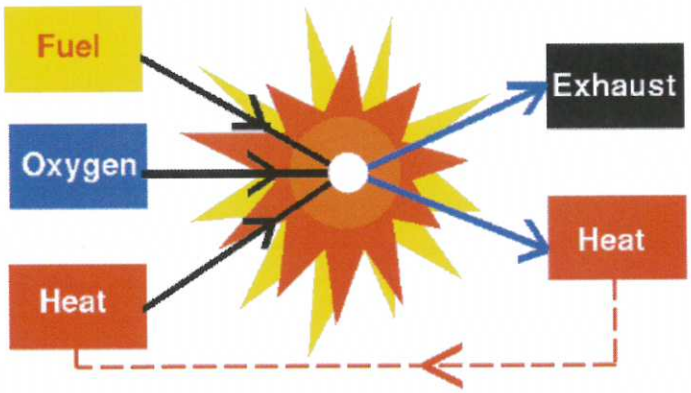
[5] Appleman, H., 1953: The formation of exhaust condensation trails by jet aircraft. *Bull. Amer. Meteor. Soc.*, **34,** 14–20.
[6] Pilie, R. J., and J. E. Jiusto, 1958: A laboratory study of contrails. *J. Meteor.*, **15,** 149–154..
[7] Scorer, R. S., and L. J. Davenport, 1970: Contrails and aircraft downwash. *J. Fluid Mech.*, **43,** 451–464..
[8] Hanson, H. M., and D. M. Hanson, 1995: A reexamination of the formation of exhaust condensation trails by jet aircraft. *J. Appl. Meteor.*, **34,** 2400–2405.
[9] Travis J.T, An Emperic model to predict widespread occurences of contrails, American Meteorology Society, Volume 36, Issue 9, September 1997.
[10] Travis D.J., Carleton A.M. and Lauritsen R.G, Regional variations in U.S. diurnal temperature range for the 11-14 September 2001 aircraft groundings: evidence of jet contrail influence on climate, Journal of Climate, Volume 17, March 1st 2004.
[11] Kalkstein and Balling Jr., Climate Research, 26, 1-4, 2004

## 3.2. CHEMICAL COMPOSITION OF CONTRAILS.

### 3.2.1. Standards for measurement:

In order to understand what is being done, we first have to understand some basic concepts. A jet engine is an internal combustion engine, just like an automobile engine is. In a jet engine, the fuel and an oxidizer combust (or burn) and the products of that combustion are exhausted through a narrow opening at high speed.[12]




The substances contained in a contrail depend on the following parameters:

- Engine type, its by-pass ratio and its pressure ratio & rated output: newer technology is usually much more environmentally 'friendly'.
- Type of fuel: modern jet engine fuel is primarily kerosene, which is a fossil fuel. However a distinction can be made between civil and military operations. Civil airplanes used in commercial aviation fly on JET A-1, while aircraft used for defense operate on a different fuel that provides optimal viscosity, heat sink and thermal stability in any operational theatre ranging from arctic to equatorial.[13] In this respect it is noteworthy that NATO-forces currently use JP-8 (Jet Propellant 8), a relative new fuel type whose additives are legally protected by a patent.
- Power setting: at take off power and cruise setting combustion is optimal, burning more than 99% of the fuel through complete combustion to carbon dioxide and water. At idle conditions, much less fuel is consumed and, in the interest of maintaining stable combustion at lower power conditions, some sacrifice in combustion efficiency occurs even though this inefficiency is still only a percent or so. Any combustion inefficiency of Hydrocarbon fuel will result in emissions of some combination of CO and incompletely oxidized Hydrocarbons, as well as some carbonaceous particles.[14]
- Maintenance standards and engine age: older engines or retrofitted power plants (e.g. upgrade to stage III of obsolete DC-8 aircraft in the years 2000 and beyond) emit significantly more pollutants than newer designs. Nano sized metal particles

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12 Picture by courtesy of Aerospaceweb.org.
13 Shawn P. Heneghan and William E. Harrison III, JP8+100: the development of high thermal stability fuel, Aerospace Mechanic Division, University of Dayton, OH and USAF Wright Laboratories, N. Wright Patterson AFB, OH, 6th international conference on stability and handling of liquid fuels, Vancouver, October 13-17 1997
14 Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft Exhaust, Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency
and AEE-300 - Emissions Division Office of Environment and Energy Federal Aviation Administration, FAA publication. May 2009.

originating as a result of wear may also appear in the contrail. The same problem occurs in countries where maintenance standards are somewhat lower.

### 3.2.2. Chemical composition of jet aircraft emissions:

Burning fossil fuels primarily produces the following gaseous emissions:[15]

- Carbon Dioxide ($CO_2$).
- A large amount of water vapor ($H_2O$) that immediately freezes upon contact with the free air. This makes the contrail visible for the human eye.
- Nitric oxide (NO) and nitrogen oxide ($NO_2$), which together are called $NO_x$.
- Sulfur Oxides ($SO_2$).
- Soot.

However very few tests have been performed in order to assess and evaluate a detailed chemical composition in terms of Hydrocarbons (HC) of contrails. Of special interest is the survey of the US Environmental Protection Agency (EPA) and the Federal Aviation Agency (FAA) of May 2009, which uses data from a set of studies initiated by NASA called Aircraft Particle Emissions eXperiment (APEX). This project was supported by a wide range of sponsors (NASA, FAA, CARB, EPA, DoD ...) and focused attention on commercial aircraft Particulate Matter (PM) emissions.

The main objective of the APEX research was to characterize both gaseous and particulate emissions to advance the understanding of emissions from commercial aircraft engines. APEX1 was conducted in April of 2004 with a NASA-owned DC-8 aircraft equipped with CFM-56-2C1 engines. APEX2 was conducted in August 2005 for typical in-use aircraft engines (CFM56 engines on B737 aircraft), APEX3 testing was conducted in October and November of 2005 spanning a range of engines from a small business jet, through a modern regional turbofan, a single-aisle transport turbofan, to a large high bypass ratio turbo fan, representing five different engine types, some measuring more than one example. In all studies, exhaust plumes were sampled at the engine exit plane and several downstream measurement locations.

Test results on the CFM56-3 engines running on JET A-1 fuel revealed that the most important compound in emissions is Ethylene, followed by Formaldehyde, Acetylene, Propene, Acetaldehyde and another 46 substances including Benzene. The most important compounds of Hydrocarbon engine emissions on a molar basis are as follows:[16]

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[15] NASA Facts, Glenn Research Center, Article FS-2000-04-010-GRC, Safeguarding our atmosphere, Glenn Research reduces harmful aircraft emissions.

[16] Shawn P. Heneghan and William E. Harrison III, JP8+100: the development of high thermal stability fuel, Aerospace Mechanic Division, University of Dayton, OH and USAF Wright Laboratories, N. Wright Patterson AFB, OH, 6th international conference on stability and handling of liquid fuels, Vancouver, October 13-17 1997 .

| Compound | Emission Ratio (mmole / mole) | Compound | Emission ratio (mmole / mole) |
|---|---|---|---|
| Ethylene | 0,770 | Acrolein | 0,061 |
| Formaldehyde | 0,572 | I-butene | 0,044 |
| Acetylene | 0,211 | Glyoxal | 0,044 |
| Propene | 0,151 | 1,3-Butadiene | 0,044 |
| Acetaldehyde | 0,135 | Benzene | 0,030 |

The other 41 compounds have a weight below 0,030 mmole per mole. Full test results are included in appendix 1, page 6.

### 3.2.3. Impact of fuel specifications on aircraft engine emissions:

In commercial and military aviation the following fuel types are being used[17]:

| FUEL TYPE | APPLICATION FIELD | REMARKS |
|---|---|---|
| JET A-1 | Commercial aviation and some air forces not being a NATO-member (e.g. Austrian AF) | Jet fuel as analyzed in paragraph 3.2.2. nowadays also used in recreational aviation & flight training, referred to for fiscal purposes as Aero Diesel. |
| JP-4 Avtag | US Airforce, NATO Code F-40 | 50/50 Kerosene – Gasoline, phased out in 1996 in favor of JP-8. |
| JP-5 | US Navy, NATO Code F-44 | Still in use in naval operations, highest flash point, higher than JET A1 and JP-8. |
| JP-7 | US Air Force | Specially designed for supersonic operations above Mach 3 (Example: former SR-71 Blackbird) |
| JP-8 | US Air Force, NATO Code F-34 | Replacing JP-4, transition should be completed by the year 2010. |

Aircraft operators are constantly refining their fuels to deal with specific performance concerns. A major problem with gasoline is that it has what is known as a low "flashpoint." This is the temperature at which it produces fumes that can be ignited by an open flame. Gasoline has a flashpoint of around 30 degrees Fahrenheit (-1 degree Celsius). This makes fires much more likely in the event of an accident. So engine designers sought to develop engines that used fuels with higher flashpoints.

The U.S. Air Force during the 1990s switched from JP-4 to JP-8 because it had a higher flashpoint and was less carcinogenic, among other things. By the mid 1990s, the Air Force further modified JP-8 to include a chemical that reduced the buildup of contaminants in the engines that affected performance. JP-5 has even a higher flashpoint than JP-8, but its high cost limits its use to aircraft carriers. JP-8 has a strong odor and is oily to the touch, which makes it more unpleasant to handle and less safe in some ways.

[17] Air BP, the history of Jet fuel, www.bp.com.

Military personnel who work with it complain that it is difficult to wash off and causes headaches and other physical problems.[18]

Market is big and ever increasing with the military operations in Iraq, Afghanistan and the restless efforts on 'war on terror'. About 60 billion gallons (227 billion liters) were used worldwide by the late 1990s, with the U.S. Air Force, Army, and NATO using about 4.5 billion gallons (17 billion liters). It is also used to fuel heaters, stoves, powered electric generators, and combat vehicles. The M1 Abrams battle tank also uses JP-8 in its gas engine turbines. The use of a single fuel for most military applications would greatly simplify wartime logistics.

A latest development is JP-8+100, a version of JP-8 with an additive that increases its thermal stability by 56°C (100°F). The additive is a combination of a surfactant, metal deactivator, and an antioxidant. It was introduced in 1994. The additive reduces coking and fouling in engine fuel systems. Commercially, this additive is used in Boeing aircraft operated by KLM, and in police helicopters in Tampa, Florida. It is also used as fuel for Canadian CF-18 Hornets.

Of special concern is the comparison between JET A-1 and JP-8 / JP-8+100. Officially the fuel types are similar, except that the military variant contains additional icing inhibitor, corrosion inhibitors, lubricants, and antistatic agents.[19] A patent protects the exact composition of additives of JP-8, which is quite obvious in order to prevent espionage and transfer of technology to hostile parties.[20] Nevertheless it is possible to establish a comparison between Jet A-1 and JP-8+100 as several civil organizations are part of the engineering program.

More than interesting is the conclusion of the 6th International Conference on Stability and Handling of Liquid Fuel, held in October 1997 in Vancouver, Canada. In this paper the effects of the selected additives in JP-8+100 are examined on properties that are unrelated to thermal stability characteristics. For instance the comparison between Jet A-1 and JP-8 of additive 'Specific Aid 8Q405' is of special interest.[21] For a given concentration the conductivity of JP-8 jet fuel is much higher, which underlines the usefulness of the proposed additives. However one can logically assume that aircraft engine emissions will also significantly increase as a result of these additional icing inhibitor, corrosion inhibitors, lubricants, and antistatic agents. Official tests results have never been released by the US government, which is also the beneficiary of the patent.

The full paper of the 6th International Conference on Stability and Handling of Liquid Fuel, as well as the detailed specifications of military aviation fuels are included in appendix 2.

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[18] www.centennialofflight.gov/essay/Evolution_of_Technology/fuel/Tech21.htm

[19] MIL-DTL-83133F 11 April 2008 Superseding MIL-DTL-83133E 1 April 1999 Detail Specification Turbine Fuel, Aviation Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37).

[20] US patent 20050274063 – jet fuel additive concentrate composition and fuel composition and methods thereof, filed June 13th 2003, published December 15th 2005.

[21] B. Dacre and J. Hetherington, Electrical Conductivity of HITTS Additive Packages for the JP-8+100 Program, Rutherford Laboratory, Royal Military College of Science, Swindon, UK, 1997, Table 1, page 325.

## 3.3. AIRCRAFT EMISSION REGULATIONS:

### 3.3.1. Regulatory standards:

Engine emissions for civil aircraft are regulated. The UK Civil Aviation Authority publishes a databank with information on exhaust emissions of only those aircraft engines that have entered production. Engine manufacturers, who are solely responsible for its accuracy, provide this information based on a test run. It was collected in the course of the work carried out by the ICAO Committee on Aviation Environmental Protection (CAEP) but has not been independently verified unless indicated. The UK CAA is hosting this Databank on behalf of ICAO and is not responsible for the contents.[22] This already reveals two weak links:

- The manufacturer provides data, based on few tests. Its reliability is not verified by any agency. Therefore one must rely entirely on the quality system of that company.
- Military aircraft are actually exempted from this regulatory system as some aircraft are equipped with engines that are no longer used in commercial aviation.[23] Although aircraft equipped with older engines mostly do not have a noise certificate and are subsequently denied landing rights on civil airports they can still cross our airspace and land on AF Bases where those restrictions do not exist.
- As ICAO only publishes standards & recommended procedures, which must be integrated into national legislation, some countries can promulgate derogations on emission regulation.

The regulatory standards are those found in the Standards & recommended procedures of the ICAO, Annex 16, Volume 2 (subsonic engines), Part III and include a standard for smoke, unburned Hydrocarbons (HC), Carbon Monoxide (CO), Oxides of Nitrogen (NOx):

| PARAMETER | REGULATORY LEVELS[24] |
|---|---|
| Smoke Number (SN) | $83{,}6 \times (F\infty)^{0{,}274}$ or 50, whichever is lower;<br>and $F\infty$ = rated engine output |
| Hydrocarbons (HC) | $Dp / F\infty = 19{,}6$;<br>and Dp = mass in grams of any pollutant emitted during the reference landing and take off. |
| Carbon Monoxide (CO) | $Dp / F\infty = 118$ |
| Oxides of Nitrogen (NOx) | Variable level in function of engine age and engine pressure ratio, ranging between<br>$DP / F\infty = 40 + 2\prod\infty$ (production before 31-12-95)<br>And $DP / F\infty = 36 + 1{,}6\prod\infty$ (engine pressure ratio 82,6 or more)<br>And $\prod\infty$ = engine pressure ratio |

Refer to appendix 3 for a detailed explanation of these parameters.

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22 ICAO Aircraft Emissions Engine Databank, UK CAA, Updated July16th 2007.

23 Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft Exhaust, Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency
and AEE-300 - Emissions Division Office of Environment and Energy Federal Aviation Administration, FAA publication. May 2009, page 3.

24 ICAO Aircraft Emissions Engine Databank, chapter 7, regulatory standards, UK CAA, Updated July16th 2007.

### 3.3.2. Case Study: civil versus military engine emissions.

#### *3.3.2.1. Outline*

The introduction of these regulatory levels was a good move to wipe out obsolete commercial jet Aircraft, unless the engine were retro fitted and upgraded to stage III.[25] Furthermore the databank includes data of engines, which do not have to comply with the emission standards, but instead received wide derogations. This clearly shows that this system is not fail safe, as it leaves too many backdoors.

In order to make a point let us examine more closely 3 different engine types:

a) The PW4048, new generation, which equips the Boeing 777.

b) The JT3D-3B that is still used on KC135 and B-52H bombers.

c) The CFM56-3C as used on the NASA APEX research as set in paragraph 3.2.2.


Engine tests on the Pratt & Whitney PW4084 as used on the Boeing 777 were performed from April 26th till May 2nd 1994 for the measurement of data for the ICAO data bank.[26]

*The KC135 tanker, which is the military version of the Boeing 707, is equipped with JT3D-3B engines, tested between 1972 and 1974. Another version, the E-3 Sentry, better known as the Awacs (Airborne Early Warning and Control System), is equipped with TF33-PW100A of Inter Turbine Technologies, which are not included in the ICAO Aircraft Emissions Engine Databank.*[27]

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[25] Air Navigation (Aircraft Noise) Regulations, Statutory rules 1984 N°188 as amended, February 22nd 2002, Office of Legislative drafting, Attorny-General's Department, Canberra, Australia.
[26] Boeing Photo, credit K63367-05
[27] Image Courtesy of the United States Department of Defence

### *3.3.2.2. Test results*

Comparison of aircraft emission data as obtained on the test data sheet between the three engine types reveals quite interesting information:

| PARAMETER | PW4084 (Boeing 777)[28] | JT3D-3B (KC135 / B52H)[29] | CFM56-3C (APEX test)[30] |
|---|---|---|---|
| Smoke Number SN (standard 50) | 10,50 | 54,50 | 9,9 |
| Hydrocarbons HC (standard 19,6) | 2,90 | 303,90 | 4,3 |
| Carbon Monoxide CO (standard 118) | 19,50 | 288,10 | 65,7 |
| Oxides of Nitrogen NOx (standard 42,69 for KC135; 79,38 for B777; 23,35 for the APEX test engines) | 62,80 | 34,30 | 53,1 |

The test results have to be interpreted as follows:

a) The data obtained with the CFM56-3C-1, labeled in green color in the table, acts as reference. This engine type meets all regulatory standards and will be used to establish the HC-emissions by the other engine types.

b) Older aircraft such as the KC135 tanker and the strategic bomber B-52H do emit substantial amounts of gaseous emissions. The NOx value of the JT3D-3B engine is lower than the data for the Boeing 777 engine due to its lower engine pressure ratio. To put in simpler words: the more engine power available the higher the emission of Nitrogen will be. This is considered as normal.

c) For some unknown reasons derogation for the JT3D-3B engine has been granted in the ICAO data sheet (see appendix 3): 395,4 for the HC-parameter and 328,2 for CO. This is in fact an increase of a very royal 2017,6% for the emission of Hydrocarbon and 278,2% for Carbon Monoxide.

d) If one extrapolates the test results as published in paragraph 3.2.2 for the CFM56-3C engine the actual weight of each chemical compound is magnified by an unknown factor. One can assume that for instance the emission of Ethylene could well exceed a hundredfold the test data of 0,77 emission ratio in mmole / mole (see appendix 1). There is no doubt that operation of airplanes with such obsolete engines has a negative influence on public health.

e) Apart from some minor airline companies on remote places the JT3D-3B engine is exclusively in use in military forces that are not subject to any restrictions of that kind. Although no data is available for engines used on the E-2 / E-3 Sentry 'Awacs' model one can assume that its emissions are similar, because some air forces such as the Royal Air Force, the French Armée de l'Air and the Saudian forces already have retrofitted their E-3's with more contemporary CFM-engines.

Copies of the ICAO documents for the 3 engine types can be found in appendix 3.

[28] ICAO Engine Exhaust Emissions Databank, Subsonic Engines, PW4084, July, 18th 2007.
[29] ICAO Engine Exhaust Emissions Databank, Subsonic Engines, JT3D-3B, October, 1st 2004.
[30] ICAO Engine Exhaust Emissions Databank, Subsonic Engines, CFM56-3C-1, October, 1st 2004.

### 3.3.2.3. Production numbers of the KC-135 Stratotanker:

In order to know if excessive emissions of these military aircraft are statistically significant one must assess how of them have been build and the percentage of military traffic in global aviation. Production of the KC135 ceased in 1965. In 1988 Boeing Company performed a mid life upgrade on 746 airplanes, clearly denoting the long active service of that airplane.[31] About 410 airframes have been upgraded since with CFM56 engines.[32]

Additionally a batch of 33 E-3 Sentry aircraft has been build of whom 17 are in use in NATO forces. These aircraft, which have not been retrofitted with CFM-engines[33], operate mainly from Geilenkirchen AFB (German – Dutch border) with a multinational crew under Luxemburg flag with apparently a civil registration number. The reason for this is quite complex. In summary official NATO sources state that it is not possible to use markings of all member countries and they had to find a member nation 'whose legislation in this area was sufficiently accommodating to provide the Force Commander with enough latitude and flexibility to make up his crews as required and organize maintenance operations'.[34] Thus Registration of the E-3As with NATO's smallest member nation, Luxemburg, was proposed.

Note the flag of Luxemburg on the tail section and underneath the wing of this E-3A at Geilenkirchen AFB. Its registration number is a civil LX-code. This airplane is still equipped with older TF33-PW100A engines (credit: official NATO AWACS website).

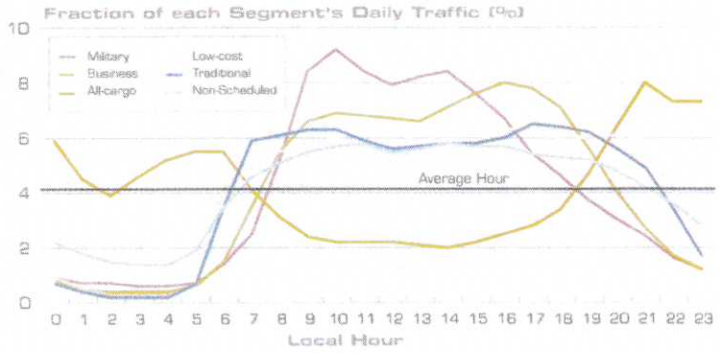
It is quite intriguing that airplanes with a Luxemburg (semi) civil registration do not need to comply with the ICAO engine emission databank and can do things at their own convenience. Furthermore Mr. D. Rumsfeld, former minister of defense under the Bush administration, declared that an upgrading program of the B-52 and KC-135 would only be partly implemented as a result of cost cutting programs.[35] A NATO survey suggests that the Awacs aircraft are 'sustainable beyond 2025'.[36] These old aircraft with high HC- and CO-emissions are likely to stay in the air for a while. The fact that Geilenkrichen AFB will not be closed in the year 2025 as planned but even see its runway extended underlines

31 Boeing Integrated Defence Systems website, Stratotanker overview.
32 CFM News, USAF expands CFM56-2-powered RC-135 fleet, July, 22nd 2002.
33 CFM News, USAF expands CFM56-2-powered RC-135 fleet, July, 22nd 2002.
34 Official NATO Airborn Early Warning and Control Force website www.e3a.nato.int, E-3A Component, FAQ, Question 14 'Why is there a red lion on the tail?'
35 Global Security, SECAF lays out case for tanker upgrade, Master sgt S. Elliott, Air Force Print News, March 7th, 2003.
36 NATO Airborne Early Warning and Control Program, US Air Force Maj. Gen. G. Winterberger, NAEW&C Force Commander and P. McCaffrey NAPMA, Plans and Evaluation Division, March 2nd, 2005.

this.[37]

### 3.3.2.4. Percentage of military traffic in global aviation:

Although the majority of air traffic on this planet is civilian, military operations represent almost the most important segment in aviation[38]:




According to the Eurocontrol statistics military traffic is actually the biggest segment between 8 AM and 3 PM. Of course not all military traffic consists of KC-135 tankers and E-3 Sentry aircraft, but one must bear in mind that very substantial resources in an Air Force are used to keep the Defense Force (Multi Role Units & Ground units in crisis zones) operational and this includes a lot of logistics in the form of transport wings. This does not only include modern aircraft as the C-17 Globemaster but also obsolete planes as the Lockheed C-130, which is still in use in many Air Forces and is not subject to study in this survey.

However, when taking into account that some part of civil cargo traffic is performed on behalf of the military then we can assume that the military segment tops above 10% at regular intervals.

### 3.3.2.5. Conclusions of this test case:

The logical conclusion obtained by combining the data as mentioned above is that the military segment is statistically important and that airplanes with excessive HC-, CO- and NOx-emissions are still widely used, although airplanes such as the KC135 and E-3 'comply' with ICAO-Standards and Recommended Procedures.

This is actually unacceptable in the view of the efforts being made by civil operators in order to comply with environmental requirements. Efforts should be made by politicians to phase out those aircraft equipped with engines that do not meet the basic regulatory levels as set in the ICAO. This encompasses the workforce of about 300 KC-135 in the United States and all of the E-3 Sentry aircraft based at Geilenkirchen. In this respect it is a total contradiction that these aircraft are allowed to operate under a Luxemburg LX-registration number, bearing in mind that its engine types are even not listed in the ICAO-databank.

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37 De Limburger, Limburgs dagblad, 'Basis Awacs blijft ook na 2025 gewoon open', December 15th, 2009.

38 Eurocontrol Trends in Air Traffic, Volume 5, Dependent on the dark: cargo and other night flights in European Airspace, 2009.

# 4. EFFECTS OF CONTRAILS ON CLIMATE

No more than a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished. We, the undersigned members of the world scientific community, warn all humanity what lies ahead. A great change in the stewardship of the Earth and life on it is required if vast human misery is to be avoided and our global home on this planet not to be irretrievable mutilated.

"World Scientists, warning to humanity", document signed by 1600 senior scientists from 71 countries, published in Time, Planet of the Year, November 18th 1992,

Publication rejected by the New York Times and Washington Post as not newsworthy

## 4. EFFECTS OF CONTRAILS ON CLIMATE:

### 4.1. Effects of contrails on cloud formation:

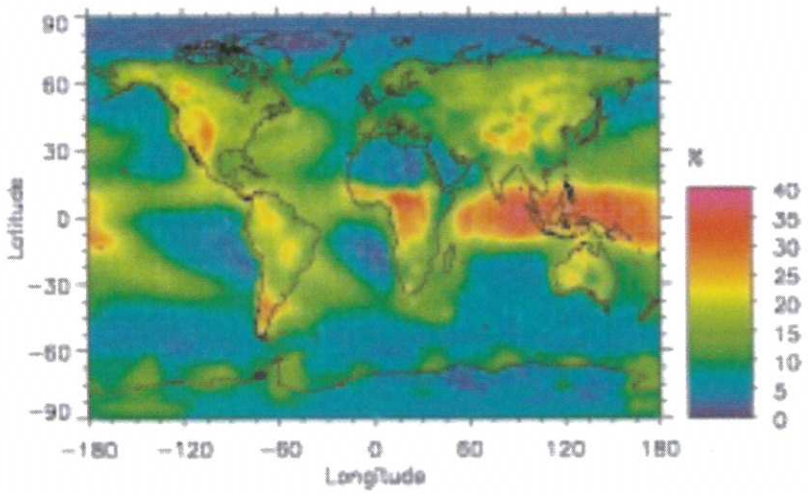
#### 4.1.1. Characteristics of Cirrus clouds:

Cirrus clouds (WMO abbreviation Ci) are formed in a natural way when water vapor freezes into ice crystals at altitudes above 8000 meters (26,000 ft) in the higher part of the troposphere. The exact altitude depends also on the height of tropopauze, the boundary with the stratosphere and the higher levels of earth's atmosphere. That means that Cirrus clouds in polar regions will appear at a much lower altitude than at the equator.

Due to the sparse moisture at a high altitude, Cirrus clouds are very thin. Fall streaks, sometimes also called Virgae, form when ice crystals fall from Cirrus clouds. The change in wind with height and how quickly these ice crystals fall determine the shapes and sizes the fall streaks attain. Since ice crystals fall much more slowly than raindrops, fall streaks tend to be stretched out horizontally as well as vertically. Cirrus streaks may be nearly straight, shaped like a comma, or seemingly all tangled together. As wind velocity increases with altitude they may be spread over large areas. This is particularly the case in the vicinity of jet streams, which splits the cells of the different tropopauze layers. Sometimes one can even see the clouds moving fast from the ground.[39]

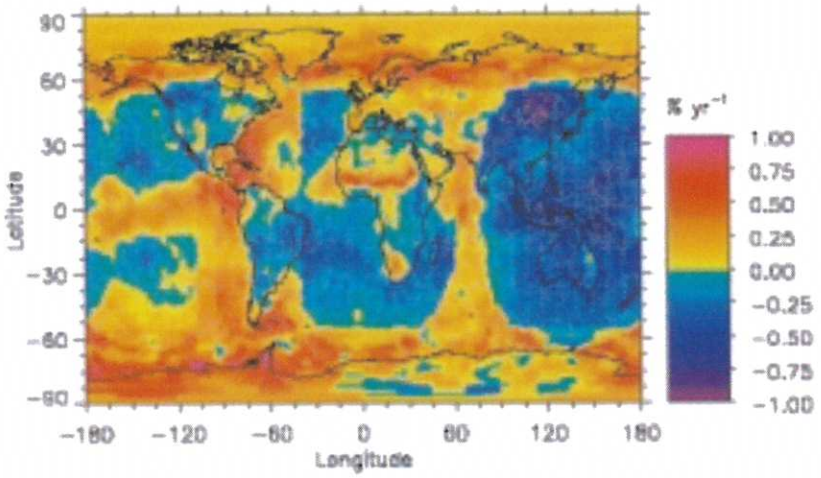
There are other cloud types associated with Cirrus such as the Cirrostratus (WMO abbreviation Cs) and the Cirrocumulus (WMO abbreviation Cc), but these are generally related to incoming frontal systems and are further omitted from this survey.

Although Cirrus clouds look thin they may occupy a significant part of the sky up to 30% and even more in some areas – in meteorological terms called 'scattered' (SCT) up to 'broken' (BKN). Transmittance of direct and diffuse sunlight is about 80%.[40]




Global map of average Cirrus cloud cover based on the ISCCP cloud database for the period 1984 - 1999 (in % cloud cover)

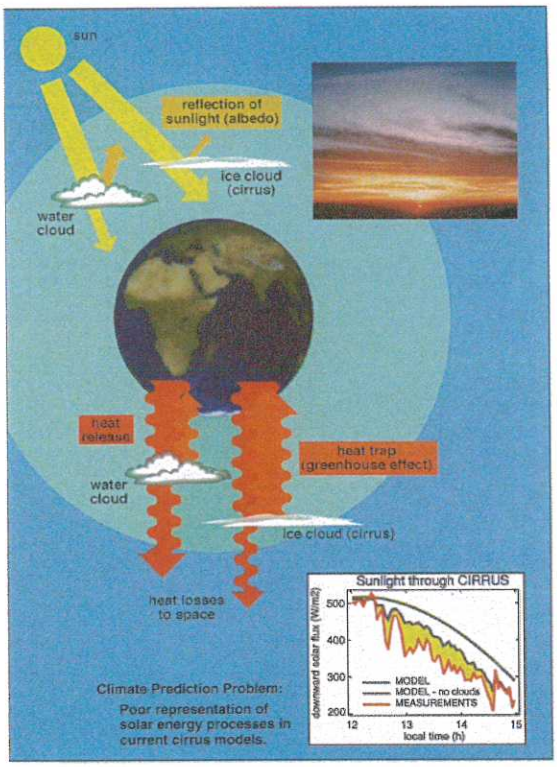
[39] WMO website, Meteoroligical Codes for high altitude clouds.
[40] Is there a trend in Cirrus cloud cover due to aircraft traffic?, F. Stordal et al., Atmos. Chem. Phys., 5, (2005) 21555-2161.




Changes in the Cirrus cloud cover in percentage between the two periods 1992-1999 and 1984-1991.[41]

### 4.1.2. Impact of Cirrus clouds on climate:

The climate of the Earth results from an energy balance between absorbed sunlight and radiative losses of heat from Earth and its atmosphere to space. Clouds are an important modulator in this balance. Clouds reflect sunlight back toward space, which reduces the solar energy available to the Earth – also called the Albedo effect. Clouds also reduce radiative heat losses to space (greenhouse effect). Which of these two opposing processes dominates depends on many parameters including cloud particle composition, cloud structure, cloud cover, and cloud location. Changes to only one of these parameters can have significant implications for climate.[42]




41 Idem as footnote 40.
42 Kinne S., Cirrus Clouds and climate, NASA Ames Research Center webpage.

The greenhouse effect is weak for low altitude clouds, so their Albedo effect dominates and they cool the Earth's climate. In contrast, cold high altitude Cirrus clouds may either cool or warm the climate. This will prove to be a key element whether to determine if weather modification programs are being conducted on the planet in order to reduce 'global warming'.

Cirrus clouds have thus a strong greenhouse effect, which may outweigh their Albedo effect losses. As the importance of both opposing effects depends critically on little understood Cirrus properties, theoretical calculations of the climatic effects of Cirrus are controversial. The main uncertainty stems from a current inability to calculate the scattering of sunlight in Cirrus clouds, since they contain a multitude of ice crystal shapes and sizes, and are irregular in structure. Even more, Stefan Kinne of the NASA Ames Research Center states clearly that the Cirrus Albedo effect is severely underestimated by calculations.[43]

This proves that knowledge in this field of science is quite limited and extensive research is mandatory in order to fully understand the impact of Cirrus clouds on climate. In this respect it is noteworthy that evidence of thin Cirrus clouds in the Stratosphere has already been established.[44]

### 4.1.3. Development of contrails into Cirrus clouds:

Contrails, a man made phenomena, are not listed as such in the WMO cloud coding. In the high cloud section of the document the only possible link with contrails is the 'Cirrus in the form of hooks, filaments, or both, progressively invading the sky' – WMO code 0509, section 4. Refer to appendix 4 for the full cloud coding as provided by the WMO.

Because contrails are not listed in the WMO decoding table there is logically no instrument to catalogue them or to make them an inherent part of a weather forecast (TAF in aviation). When contrails turn into Cirrus clouds they are just incorporated in the actual weather report (METAR in aviation). As there are no instruments for measurement most meteorologists just limit their impact on climate as being only 'esthetic'.

Not all contrails develop into Cirrus clouds and if they do, what is the exact scientific base? Well, aircraft emissions as explained in paragraph 3.2.2. are actually aerosols, microscopic particles suspended in the air.[45] They act like seeds: water molecules can condense or freeze on to them to form cloud particles.

Sulpheric Acid ($H_2SO_4$) increases as a result of gas-phase oxidation processes. Soot particles become chemically activated by adsorption and binary heterogeneous nucleation of Sulphur Trioxid ($SO_3$, a chemical compound of Sulphur and Oxygen) and $H_2SO_4$ in the presence of $H_2O$, leading to the formation of a partial liquid $H_2SO_4/H_2O$ coating. Upon further cooling, volatile liquid $H_2SO_4/H_2O$ droplets are formed by binary homogeneous nucleation, whereby the chemi-ions act as preferred nucleation centers. These aerosols grow in size by condensation and coagulation processes (clotting).

Coagulation between volatile particles and soot enhances the coating and forms a mixed $H_2SO_4/H_2O$-soot aerosol, which is eventually scavenged by background aerosol particles at longer times. If liquid $H_2O$ saturation is reached in the plume, a contrail forms. Ice particles are created in the contrail mainly by freezing of exhaust aerosols. Scavenging of exhaust particles and further deposition of $H_2O$ leads to an increase of the ice mass. The

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43 Kinne S., Cirrus Clouds and climate, NASA Ames Research Center webpage.

44 Keckhut P., Hauchecorne A., Bekki S., Colette A., David C., and Jumelet C., Evidences of thin Cirrus clouds in the stratosphere at mid-latitudes, Service d'Ae´ronomie/Institut Pierre-Simon Laplace, CNRS, Verrie`res le Buisson, France, Received: 28 December 2004 – Accepted: 17 January 2005 – Published: 21 June 2005

45 NASA Facts, Glenn Research Center, Article FS-2000-04-010-GRC, Safeguarding our atmosphere, Glenn Research reduces harmful aircraft emissions.

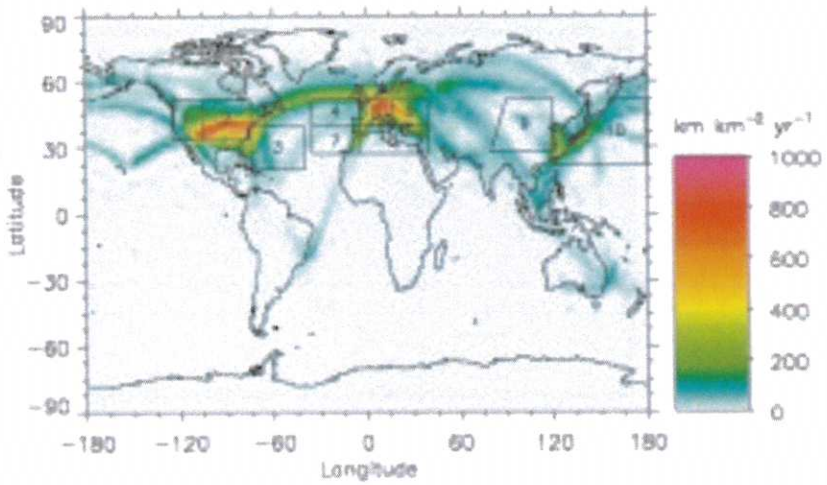
contrail persists in ice-supersaturated air and may develop into a Cirrus cloud. Short-lived and persistent contrails return residual particles into the atmosphere upon evaporation. The scavenging timescales are highly variable and depend on the exhaust and background aerosol size distributions and abundances, as well as on wake mixing rates.

This means that the formation of contrails not only depend on the amount of HC-, CO and NOx engine emissions but also on the fuel type being used. In this respect it is likely that older engines operating on fuels with additional additives as highlighted in the case study produce more persistent contrails.

### 4.1.4. Impact of aviation on the formation of men made 'Cirrus':

Before discussing the possible impact of contrails on climate one has to assess the most popular flying routes as well as the projected evolution of aviation on the globe.

The most congested traffic patterns are situated between the East and West coast of the United States, overhead the North Atlantic and between major cities in Europe. When we look at the trend in commercial aviation the number of flights may well double in the next ten years. In order to avoid airspace saturation on the busiest routes Air Traffic Control agencies such as CANAC in Brussels anticipated this development by introducing new transponders (Mode S) in November 2009 to allow smaller separation standards between airplanes.




This map shows the distances flown with aircrafts for the year 2000 between 9800 and 11600 m altitude. It shows also 10 regions from which a correlation between aircraft density and Cirrus trends has been analyzed and proven.[46]

[46] Is there a trend in Cirrus cloud cover due to aircraft traffic?, F. Stordal et al., Atmos. Chem. Phys., 5, (2005) 21555-2161.